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THE PRODUCTION OF ZOOPLANKTON IN A LANDLOCKED FJORD

THE NORDÅSVATN NEAR BERGEN, IN 1941-42

By
Kristian Fredrik Wiborg

ON THE TIDAL WATERS IN THE NORDÅSVATN

By
Bjørn Vindenes

SAMBAANDETS TRYKKERI — BERGEN 1944

CORRECTIONS

Page	Line	For	Read
11	37	H. Vindenes	B. Vindenes
18	2	page 16	page 15
50	8	October 10. 1941, May 2.	October 3. 1941, May 22.
69	25	15—50 m layer	15—30 m layer.

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With special reference to the copepods

40 figures, 7 tables

By
KRISTIAN FREDRIK WIBORG

SAMBAANDETS TRYKKERI — BERGEN 1944

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PREFACE

In 1941 the Fisheries Directorate of Norway initiated investigations in the Nordåsvatn (the Fjøsanger Fjord) near Bergen for the purpose of studying the plankton production. Weekly observations were carried out continuously from May to October 1941 and from April to July 1942, with additional observations in December 1941 and September 1942. During these periods hydrographic and chemical observations were made and samples of zoo- and phytoplankton collected. The material of phytoplankton has been handed over to the Botanical Laboratory at the Oslo University and is in preparation. The hydrographic-chemical observations and the zooplankton material have been coordinated by the present author, who has also had the supervision of the investigations.

I wish to express my gratitude to Mr. G. Rollefsen, Scientific adviser of Fisheries, who made it possible for me to undertake these investigations. To Messrs. Olav Åsen and Peder Soleim, who have taken part in most of the cruises and given me much valuable advice, I give my varmest thanks. I also wish to thank Messrs. K. Wilhelmsen, F. Kjellstrup Olsen and W. Rasmussen, who have worked out parts of the chemical analyses and the hydrographic material, and assisted with drawings and tables.

The leader of the Oceanographic Section, dr. J. Eggvin, has kindly placed his laboratory at my disposal and perused the hydrographic part of the manuscript.

Fisheries Directorate, Marine Research Branch, Bergen.

Kristian Fredrik Wiborg.

Introduction.

Previous investigations.

The hydrography of the Nordåsvatn, mainly concerning the aeration and hydroxylion concentration, has been thoroughly investigated by Gaarder (1916 and 1919). A few plankton observations concerning medusæ are recorded by Kramp and Damas (1925). Nordgaard (1898, 1899, 1901, 1910 and 1912) and Runnstrøm (1932) have investigated the animal plankton in adjacent waters near Bergen. Münster Strøm (1936) has some observations on hydrography and bottom deposits from the Nordåsvatn.

Material and methods.

The observations in the Nordåsvatn were made at three main stations, Paradisholmen (station 1), Marmorøya (st. 3) and Bønes (st. 5) (See chart, fig. 1). The station at Kråkenes (st. 2) was visited regularly from May 2. to June 13. 1941. Later it was replaced by the Paradisholmen station. This is indicated by a vertical line in the isopleth diagrams. The station at Sjøviknes (st. 4) was visited a few times.

Observations were carried out weekly from May 2. to October 10. 1941. Later on ice hindered the work, but we were enabled to take the stations on October 24. and on December 1. and 12.

In 1942 the observations stretched from April 10. to July 14. with interwals of 1—2 weeks. The stations were visited for the last time on September 18.

At Marmorøya water samples were at first taken from 0, 1, 2½, 5, 10, 15, 20, 25 m and each 10 m from 30 to 80 m. Later on, from October to Desember 1941, the 50—80 m samples were cut out. After May 22. 1942 the 20, 30, 50 and 70 m were discontinued. At the other stations the intervals of depth were somewhat wider.

Each water sample was examined as to temperature (in situ), salinity, oxygen, — and phytoplankton (the Marmorøya station only). At each station vertical hauls were made with a closing net «8/72».

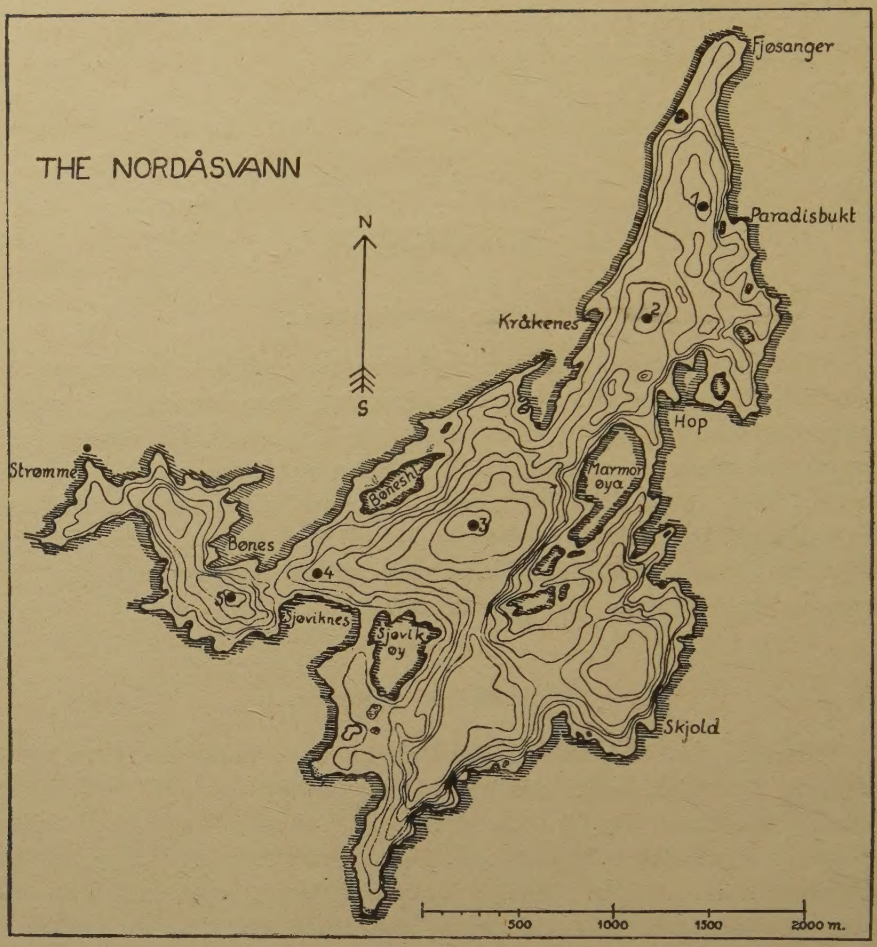

Fig. 1. The Nordåsvatn. Hydrographic and plankton stations 1941—42 marked with •

(Nansen's net, diameter 72 cm, silk no. 8 in the conical part). The hauls were taken in 2—4 steps according to the temperature in the different water layers. For the reading of temperature reversing thermometers were used in combination with water bottles of Nansen's construction. The salinity was determined in the ordinary way, on the basis of chlorinity determinations against standard water, and the oxygen content after Winkler's method. The phytoplankton samples were fixed in neutralized formalin. The zooplankton samples were also immediately fixed in formalin.

In the further work on the zooplankton the animals first were determined and counted. Because of the great number of organisms the samples were divided by means of Lea's Plankton Divider (See

Wiborg 1940). Of the samples 1/10 to 1/100 was counted according to the size of the material. Finally the entire sample had a cursory inspection.

Measurements were undertaken with a Leitz binocular microscope with a built-in micrometer. After the size of the objective, 1 division corresponds to 0.1, 0.033 and 0.0084 mm.

For identification of species were used «Nordisches Plankton» and «Tierwelt der Nord- und Ostsee» (See references), for the copepods chiefly G. O. Sars: «An Account of the Crustacea of Norway», IV, V and VI.

T in the tables indicates that the species in question is sparsely present.

Topography and hydrography of the Nordåsvatn.

Topography.

The Nordåsvatn (the Fjøsanger Fjord) is situated about 5 km south of Bergen. The length is 5 km, the greatest breadth 2 km. The only connection with the outer fjords is a narrow channel, 10 m wide, 30—40 m long and 3 m deep, in the western part at Strømme. The chart (fig. 1) is worked out on the basis of soundings made by the Norwegian Geographical Survey in 1935. The isobaths are drawn for each 10 m. The bottom formation is somewhat complicated and consists of a series of basins divided by ridges. A threshold at Bønes rising to 12 m depth divides the Nordåsvatn into an outer and an inner fjord.

The two basins in the outer part have a maximum depth of 45 and 53 m respectively, the connection between them being 30—35 m deep. Inside Bønes we find the basins at Marmorøya (84 m), at Sjøvikøy (69 m), and at Skjold (66 m). The connections between them are 30—35 m deep. North of the Marmorøya basin the bottom is comparatively even, shoaling up towards Fjøsanger.

Hydrography.

Gaarder (1916 and 1919) made a thorough investigation of the aeration and hydroxyl-ion concentration in the fjords around Bergen, among them also the Nordåsvatn. His observations stretched from August 1912 to May 1914, but the Nordåsvatn stations were visited only 8 times during this period. According to his investigations the

Nordåsvatn has much the character of a landlocked water or «poll». It may be divided into an outer and an inner fjord, separated by the threshold at Bønes. The upper water layer, measuring 12—15 m, is well aerated, mainly on account of the tide currents. In the upper 1 m there is a layer of real brackish water, but below 1 m the salinity is always higher than 23 pro mille. The transition between the surface layer and the bottom water is very distinct. In the inner fjord the bottom water may be stagnant for years, and, as a rule, contains H_2S. This also happens in the outer fjord, but there the bottom water is renewed regularly, at least once a year. This renewal generally takes place in winter and early spring. In the inner fjord the bottom water is being renewed in years with little precipitation and during otherwise favourable conditions. Exceptionally, a renewal may take place in summer (loc. cit. 1916, pag 77—78).

The hydrographic conditions in 1941—42.

As the observations were carried out with weekly intervals, we are enabled to give a more detailed description of the changes in the hydrographic situation. The main features, however, are the same as those found by Gaarder.

In order to show the characteristics of the hydrographic situation in the Nordåsvatn in 1941, I have in fig. 2 set up the distribution of temperature and salinity on July 18th 1941.

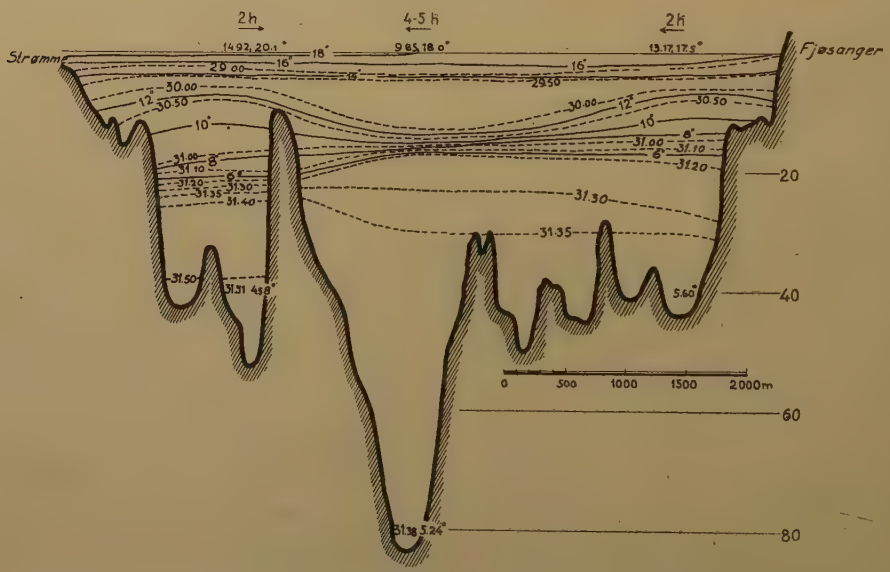

Fig. 2. Distribution of temperature and salinity July 18th 1941.

Both in respect to temperature and to salinity the stratification is very pronounced. In the inner fjord there is a rapid fall in temperature from 18.0° C to 5.5° C from 0 to 20 m, in the outer fjord from 20.1° C to 4.6° C from 0 to 25 m. The deeper water layers are mostly uniform, measuring 5.5°—5.2° C in the inner fjord, 4.6°—4.4° C in the outer part. The salinity at the surface is very low, 9.9—14.9 pro mille, but not more than 1 m down it surpasses 27 ‰. Towards deeper water the salinity gradually increases to reach about 31 ‰ at 15 m. The bottom water has a salinity of 31.36 ‰ in the inner fjord, about 31.50 ‰ in the outer part. The transition from the surface layer to the bottom water is very distinct, the transition layer stretching from 12 to 20 m in the inner fjord, 15 to 25 m in the outer part.

The isotherms and isohalines do not run so close together in the outer fjord as in the inner part. The surface layer there will be comparatively well mixed on account of the tidal currents.

In the inner fjord, the isohalines and isotherms in the surface layer have a wavelike course, with the trough of the wave at Marmorøya. These wave-like isopleths are often found in the Nordåsvatn, and may possibly be referred to internal waves. In a closed water system, like that of the Nordåsvatn, with a relatively distinct border between bottom water of high density and surface layer of low density, internal waves will easily arise in the transition layer (Ekman 1931). These originate in various ways. Constant north-easterly or south-westerly winds will stow the surface water into the outer or inner part of the inner fjord. The transition layer will then be displaced from the horizontal position into an oblique one. When the wind ceases, the bottom water will tend to attain its former level. In the Nordåsvatn we have mainly south-westerly winds. Tide currents probably are the main influencing factor. If the water in the tide current, coming in through the outer basin and passing the threshold at Bønes, has a higher density than that of the surface water of the inner fjord, but a lower than that of the bottom water, it will press down the upper border of the bottom layer.

In fig. 3 the isopycnes are drawn for the stations in the Nordåsvatn on June 13. 1941. For each station is indicated the direction of the tide current and the approximate time since last high or low water, calculated after the observations of H. Vindenes (1944). It will be seen that the isopycnes have a characteristic wave-like course.

These waves are of a certain importance when we discuss the vertical distribution and vertical movements of the zooplankton. G. Rollefsen has kindly given me information of the occurrence of internal waves in the Vestfjord, Lofoten. The period of oscillation

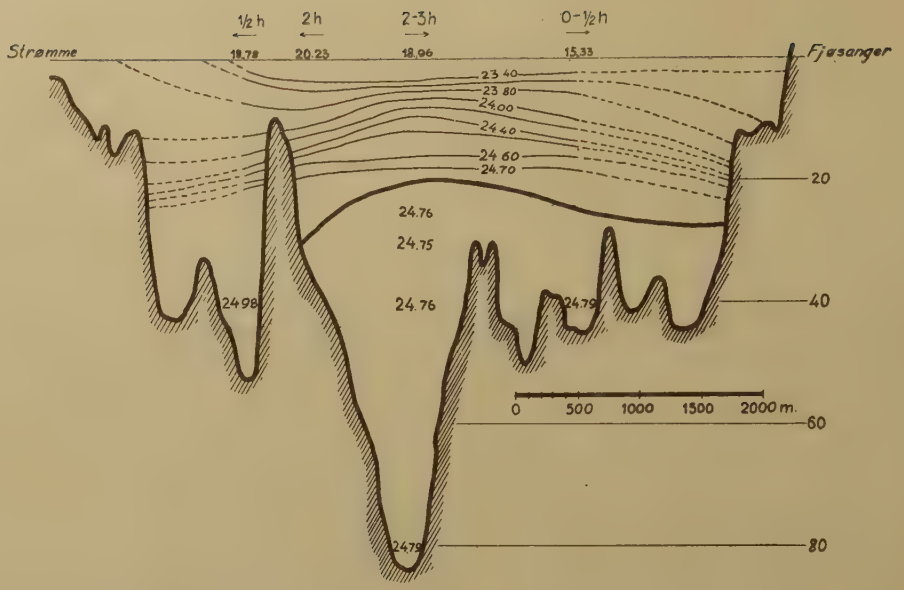

Fig. 3. Distribution of density June 13th 1941. Thick line, border of H_2S layer.

lasted about 12 hours, and in relation to this the quantity of plankton (eggs of cod) in the different water layers varied considerably.

These waves are mentioned also by Münster Strøm (1936).

I cannot here discuss the problem of internal waves any further, but only indicate their existence in the Nordåsvatn, and the factors possibly influencing their origin. Most probably there will also be found standing waves there.

The variations in salinity during 1941—42 are shown in fig. 4 for the outer fjord, and in fig. 5 for the inner fjord.

In the surface layer, the salinity is influenced by drainage and rainfall. Two small brooks and several rills run into the Nordåsvatn. The upper 1 m generally consists of brackish water, with a salinity varying between 2 and 29 $^0/_{00}$ during the course of the year. This is most marked in the inner fjord. In cold winters the Nordåsvatn is covered with ice, thus, during the winter 1941—42, the ice-cover lasted from the end of December 1941 to April 17. 1942.

In the layer from 1 to 20 m there were in 1941 variations in salinity from 24.0 to 31.3 $^0/_{00}$, mostly from 28 to 31 $^0/_{00}$. In 1942 the variations were from 25.0 to 31.8 $^0/_{00}$.

In the transition layer between the surface water and the bottom water the isohalines run somewhat closer together in the inner than in the outer fjord.

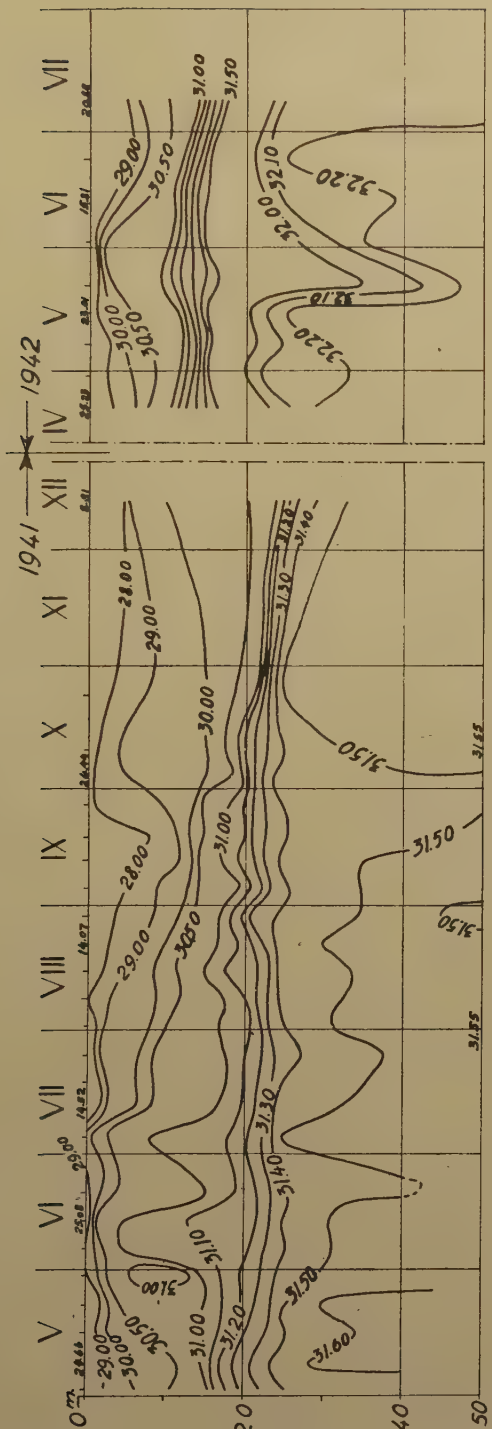

Fig. 4. Salinity isopleths at Bønes.

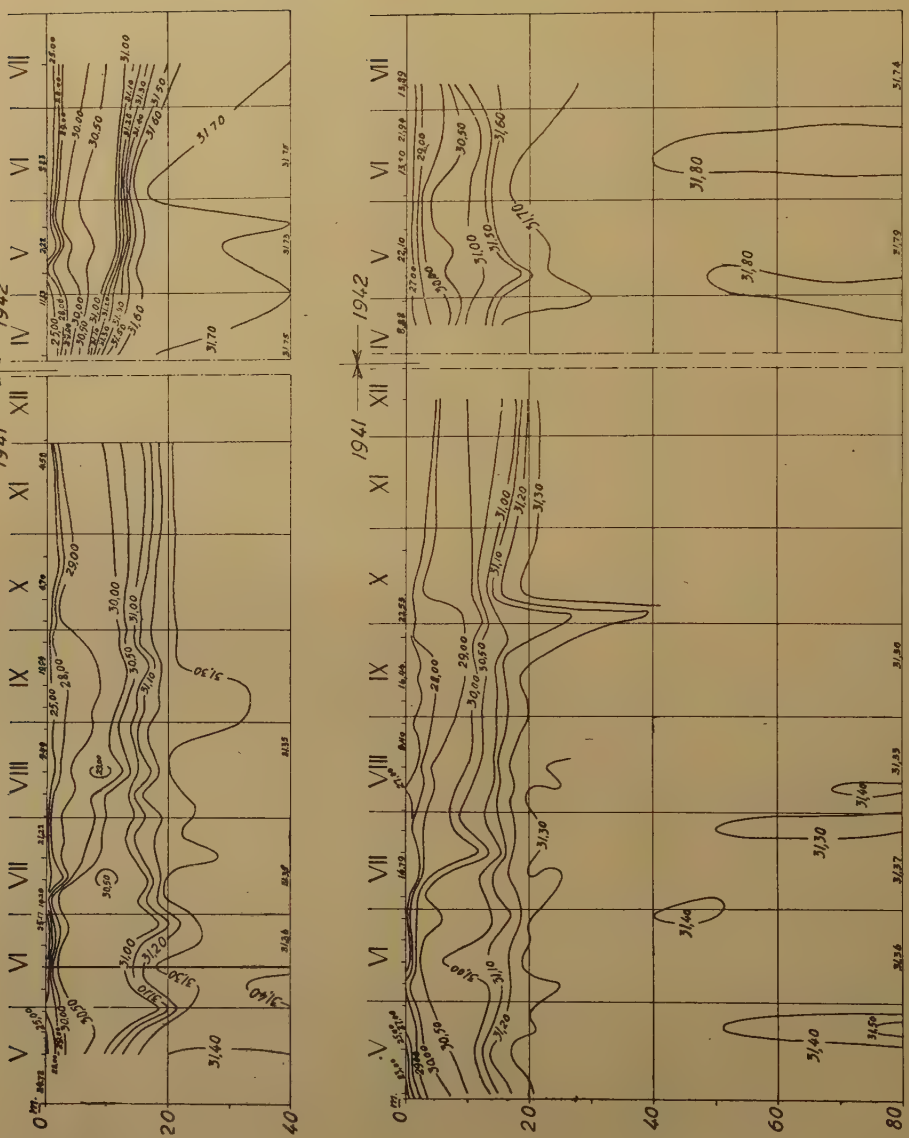

Fig. 5. Salinity isopleths at Paradisholmen (upper fig.) and Marmorøya.

In the inner fjord the water below 20 m depth is fairly homogeneous with salinities of 31.2—31.4 ‰ in 1941, 31.6—31.7 ‰ in 1942. The difference between the two years is caused by a total renewal of the bottom water during the winter 1941—42, which will be discussed later on. The salinity is very low, compared with the water layers in corresponding depths in the fjords outside the Nordåsvatn.

The Geophysical Institute, Bergen, has kindly placed at my disposal some hydrographic material from the Marmorøya station for the years 1913, 1916, 1917, 1919, 1920, 1921, 1923 and 1927. Below 20 m the salinity generally varied between 30.4 and 30.9 ‰ in these years. An exception was March 26. 1913 with 29.59—30.05 ‰. In 1923 and 1927 the variations were 31.0(28.5)—31.2 ‰. Münster Strøm has some observations from the same station on June 15. 1932 (pag. 24, 1936). The salinities range from 30.6 to 31.0 ‰ from 20 to 75 m.

Isopleths for temperature in 1941—42 are shown in fig. 6 for the inner fjord, in fig. 7 for the outer part.

In the inner fjord the yearly variations below 15—16 m are insignificant. On some occasions, e.g. in June and July 1941, the isotherms drop towards 19—20 m, probably due to an influx of water from the basin in the outer fjord, or, perhaps, to internal waves. In summer stratification is very pronounced, especially in the upper 2.5 m, e.g. at Marmorøya July 25. 1941: In 0 m 21.4° C and in 2.5 m 15.5° C, at Paradisholmen August 8. 1941, in 0 m 13.8° C, in 0.1 m 15.0° C, in 0.25 m 15.9° C and in 1 m 16.3° C. Also in the transition layer the temperature gradient is great, e.g. at Paradisholmen August 29. 1941, in 10 m 15.1° C, and in 15 m 6.9° C.

In the outer fjord (fig. 7) the yearly variation is particularly remarkable in the upper 20 m. The isotherms do not run so close together as in the inner fjord. There are small yearly variations in the layers below 20 m in the inner fjord, and below 25 m in the outer fjord, apart from those caused by the renewals of the bottom water.

The temperature variations in the deeper water layers were as follows:

Marmorøya

	1941	1942
20 m level	5.68° C—6.09° C	4.48° C—5.40° C
80 m »	5.04° C—5.35° C	4.21° C—4.33° C

Bønes

	1941	1942
25 m level	4.32° C—6.36° C	3.99° C—4.38° C
50 m »	4.49° C—4.89° C	4.04° C—4.25° C

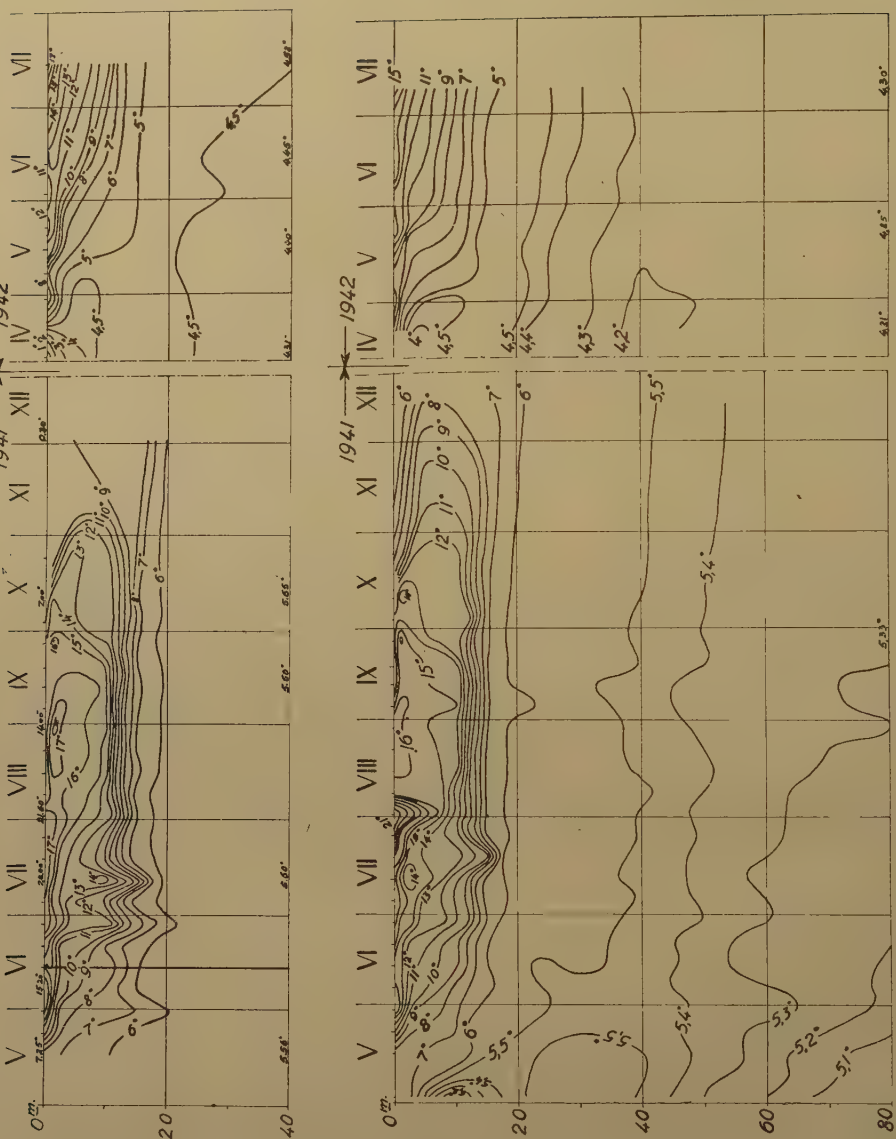

Fig. 6. Temperature isopleths at Paradisholmen (upper fig.) and Marmorøya.

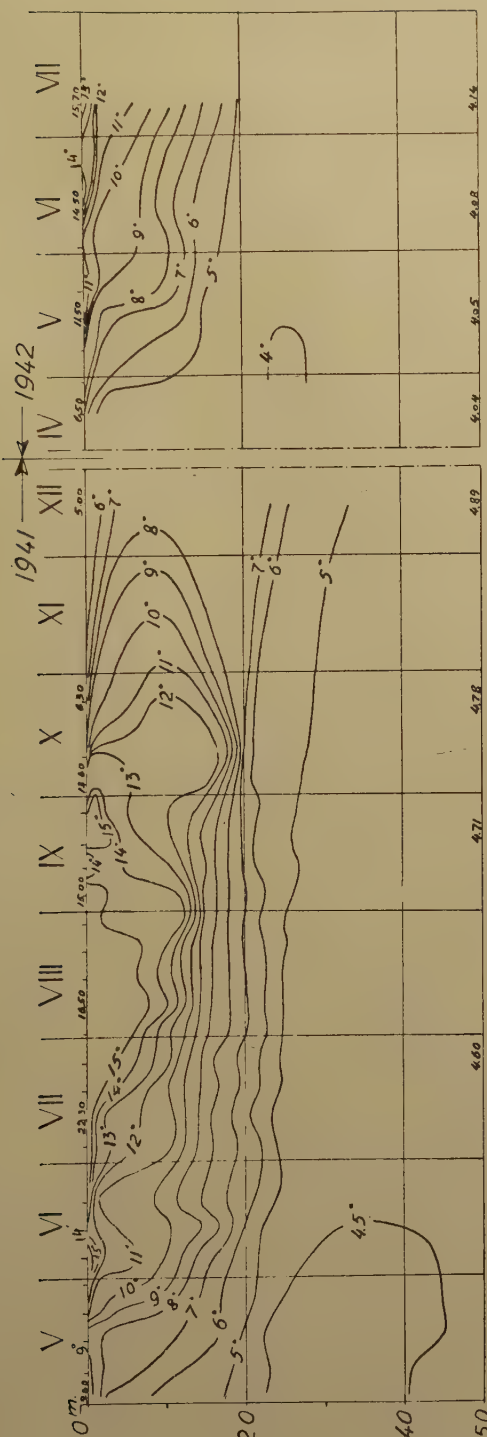

Fig. 7. Temperature isopleths at Bønes.

Observations from the station at Marmorøya for the years 1913—1927 (see page 16) have shown that the bottom temperature varies considerably from year to year. March 26. 1913 it was 6.28° C at 75 m, and August 30. of the same year 9.20° C. This difference was caused by a renewal of the bottom water during the summer (dealt with by Gaarder 1916). Generally temperatures between 5.5° C and 6.0° C were found at the 75 m level.

Münster Strøm (1936) has a record of 6.28° C at the 75 m level on June 15. 1932.

The distribution of density in 1941—42 is shown in fig. 8. The isopleths for σ_t have the same course both in the inner and outer fjord, but in the inner fjord they run more wavy and at a somewhat higher level. The isopycne of 24.70 runs at 20 m level most part of the year, except in September, when it drops down to 40 m. The deep water layers have very small changes in density. Also in the outer fjord there is a relatively pronounced instability in the water below 20 m, the density increasing from 24.50 to 25.00 towards the bottom.

In 1942 the density of the new water masses that have been carried in, is greater than that of the water present in 1941. The isopycne 25.00 is now found at the 15 m level in both parts of the Nordåsvatn. The layer below 20 m is very homogenous both in the outer fjord (25.40—25.60) and in the inner part (25.10—25.20).

The aeration of the Nordåsvatn in 1941—42.

Isopleths for oxygen content in ml/l and percentage of saturation in the basin at Bønes in 1941—42 are shown in fig. 9.

In 1941, the upper 15 m layer is well aerated. The oxygen content are, as a rule, more than 5 ml/l, the percentage of saturation more than 80 %, in the upper 10 m above 100 %, except from October to December. Maximum percentages in the upper 5 m occurred in May, July and September, and were probably due to the phytoplankton.

From 15 m the oxygen content decrease rather rapidly to 25 m. In this layer the yearly variation is not great. Generally there is equilibrium between the supply and consumption of oxygen. From 25 m the oxygen content decrease slowly towards the bottom. In May 1941 the bottom water was comparatively well aerated, and had probably been renewed during the winter and the early spring of 1941. On May 2. the following percentages of saturation were observed:

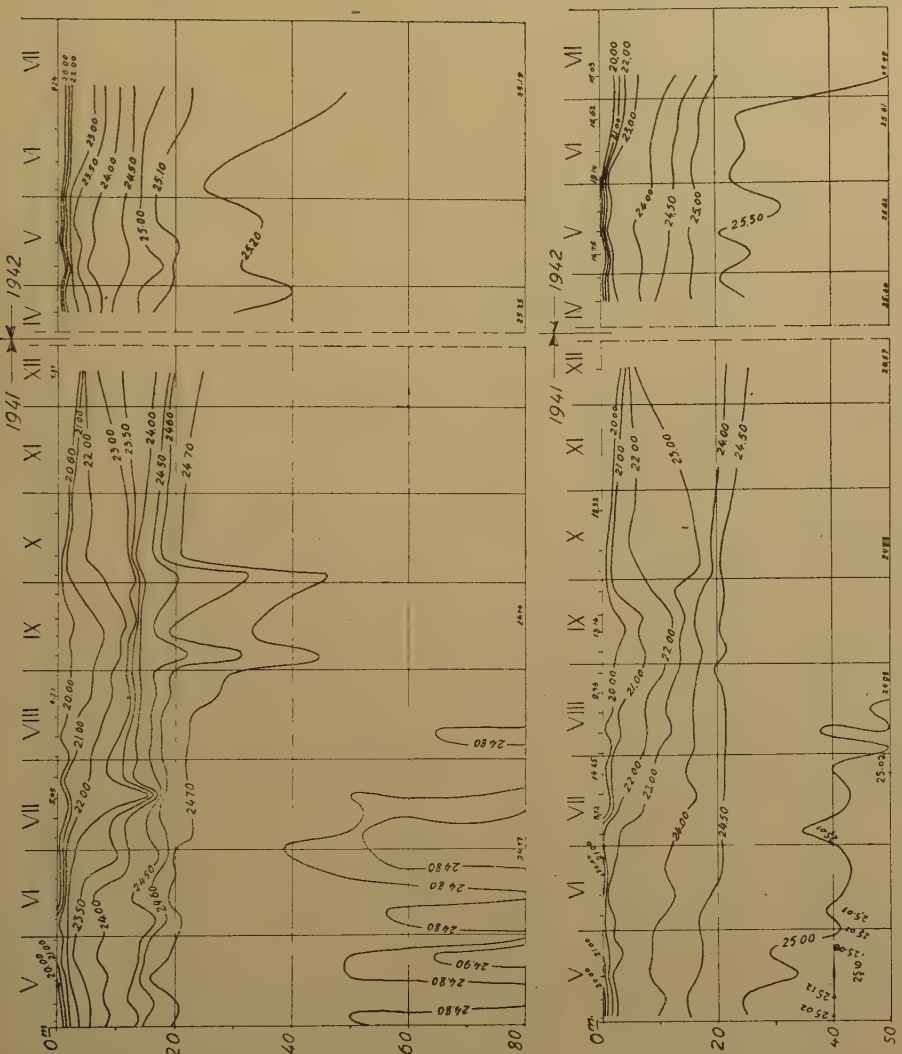

Fig. 8. Density isopleths at Marmorøya (upper fig.) and Bønes.

Depth, m	0	2½	10	15	25	40
Oxygen, % sat.	126.2	118.1	87.8	53.5	64.7	45.6

The minimum percentage at 15 m indicates that the renewal had taken place recently. This minimum layer probably at first belonged to the bottom water of the inner fjord, which had been lifted up and carried into the outer fjord (see page 24).

In the course of the year the oxygen below 20 m is being gradually consumed and the fall in percentage of sat. from 50 to 1 % proceeds with almost constant speed. A comparatively long time, however, has passed before the last traces of oxygen have disappeared. The consumption is mainly caused by bacterial action (decaying processes) and oxydation of organic matter, etc. In December 1941 there were still traces of oxygen near the bottom.

In the winter and the early spring of 1942 a very extensive renewal took place in the deeper water layers. The distribution of oxygen in the different depths in April was similar to that in May 1941, although much more pronounced. The distribution of oxygen on April 21. was as follows:

Depth, m.	1	2½	5	10	15	20	30	40	50
Oxygen, % sat.	98.0	96.7	90.0	50.0	39.0	49.7	53.5	52.6	46.1

We have a minimum at 15 m. Near the bottom the percentage of oxygen is not much below that in 30 m. The renewal probably has taken place recently or has not yet been finished.

The transition layer is situated between 10 and 15 m, or above the level attained in 1941. Normal conditions are gradually reestablished during June and July. In the layer below 20 m the oxygen is again consumed gradually but more rapidly than in 1941, the isopleths for oxygen running more steeply. The last traces of oxygen are hovever consumed slowly. On July 8. there were percentages of 27.2 and 11.5 in 25 and 50 m respectively. On September 18. the respective values were 6.7 and 0.7 %. The variations in the upper 10 m were similar to those of 1941 with percentages over 100 in May and June.

The inner fjord.

The variations in oxygen content at Paradisholmen are shown in fig. 10 and the variation in oxygen content and percentage of saturation during 1941—42 at Marmorøya in fig. 11.

In the upper 15 m the isopleths for oxygen run nearly correspondent to the isotherms in 1941. The upper 10 m are well aerated.

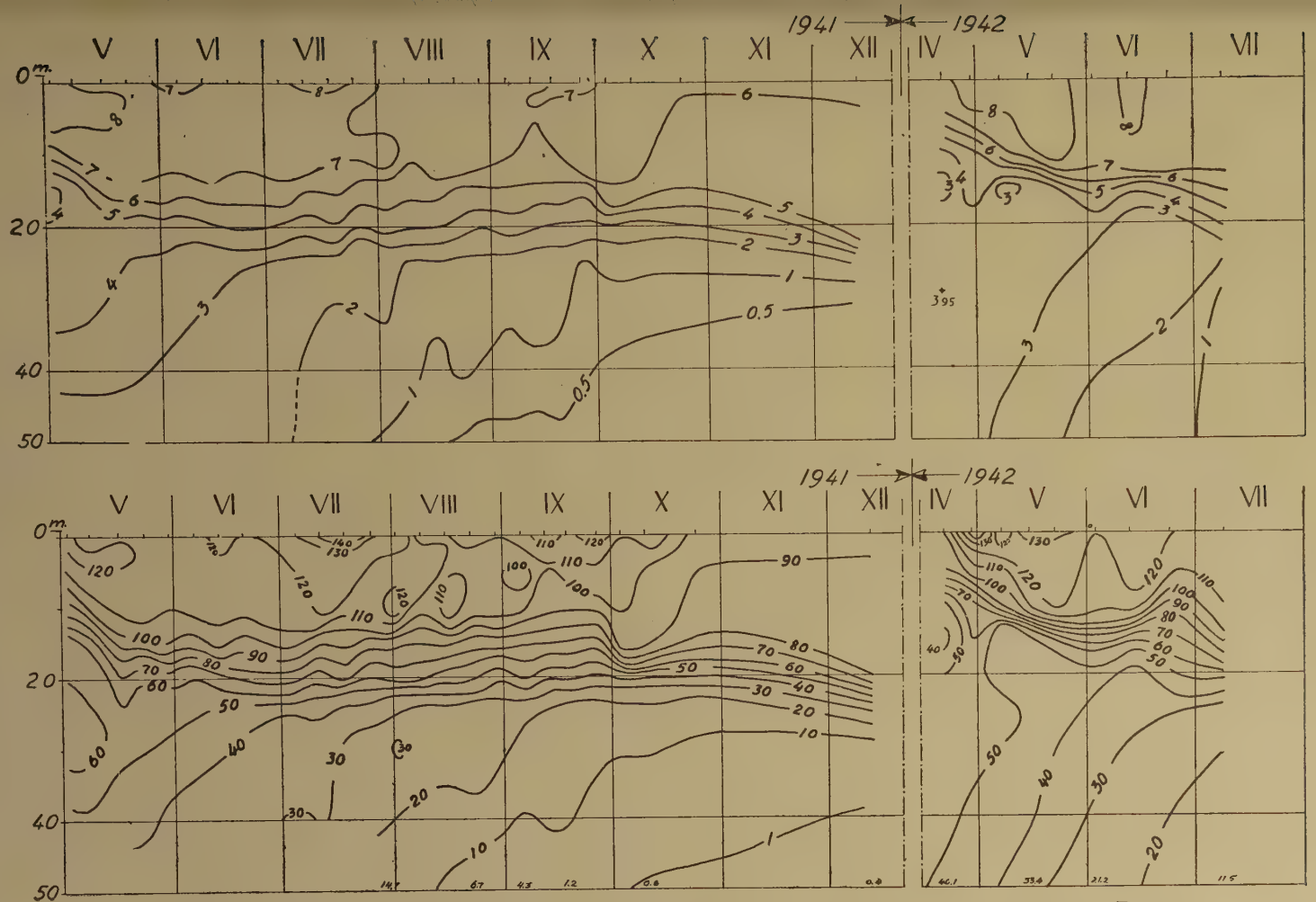

Fig. 9. Isopleths for oxygen content in ml/l (upper fig.) and percentage of saturation at Bønes.

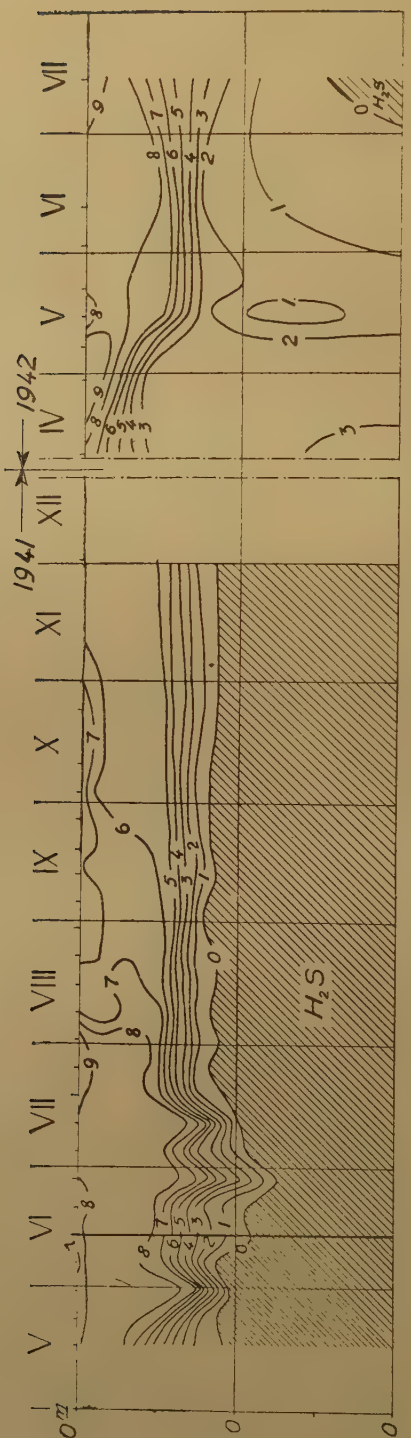

Fig. 10. Isopleths for oxygen content in ml/l at Paradisholmen.

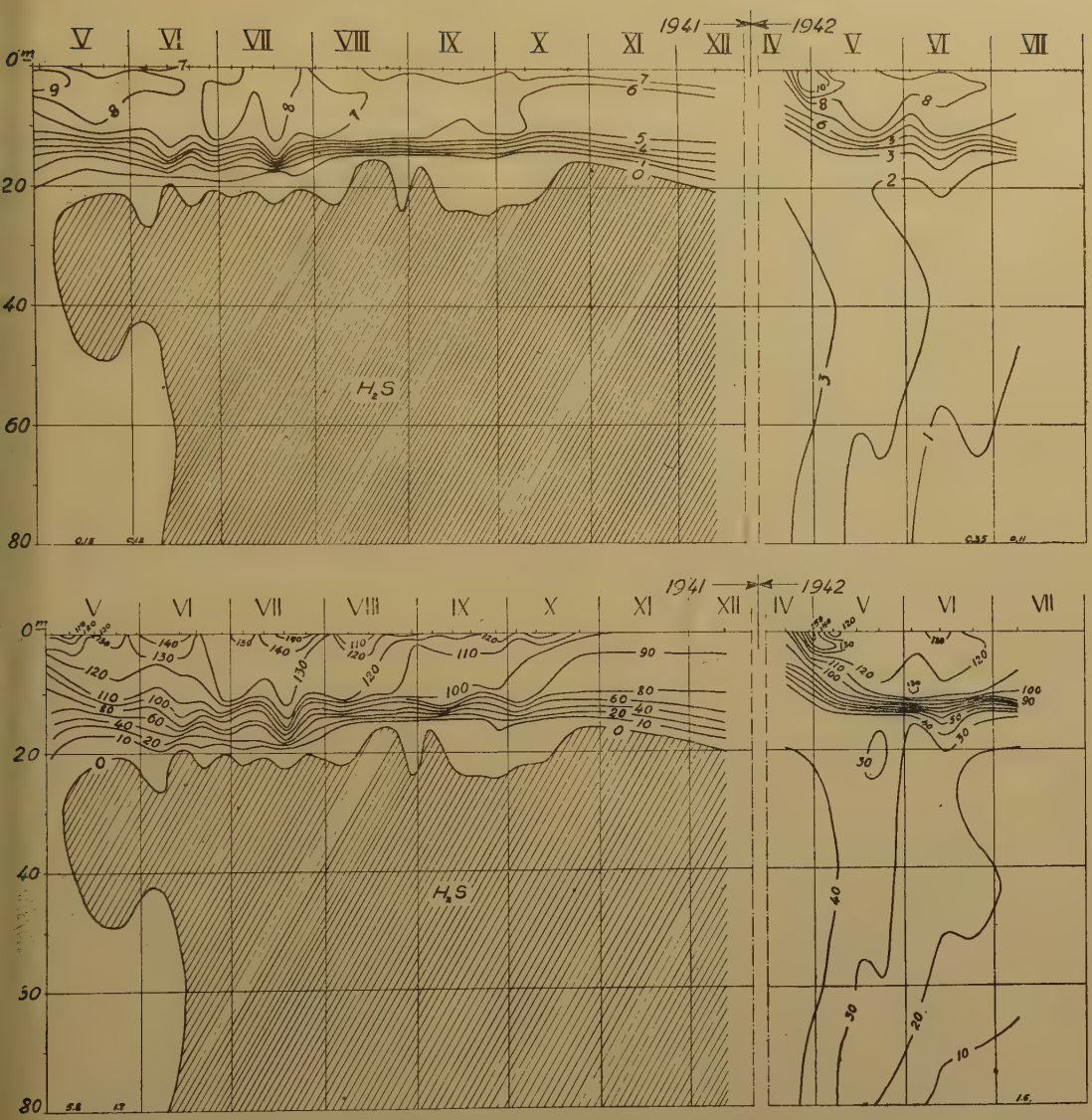

Fig. 11. Isopleths for oxygen content in ml/l (upper fig.) and percentage of saturation at Marmorøya.

The oxygen percentage surpasses 100, with marked maxima in May, June, July, and August. The highest oxygen content, more than 9 ml/l, occurred at Paradisholmen on July 25. at 1 m level, with a saturation of 159.0 %. The isopleth for 120 % goes down to 10 m level from the end of June to the beginning of August. From 10 m the oxygen content rapidly decrease towards 15—20 m. The isopleths run close together, especially in August.

From May to the middle of June 1941 an intermediate layer of H_2S was observed between 20 and 50 m level at Marmorøya. The following table shows the distribution of oxygen, % of sat. and H_2S from the 10 m level and downwards:

Date	29/4	2/5	8/5	16/5	23/5	30/6	6/6
10 m	72.8	89.3	99.8	112.4	114.7	112.2	107.8
15 m	—	37.2	26.5	22.2	34.4	44.6	56.5
20 m	—	—	—	—	—	—	3.0
25 m	H_2S	0.56	H_2S (0.4)	H_2S	H_2S	H_2S	H_2S (0.6)
50 m	2.5	2.9	2.5	0.56	0.14	0.8	1.0
80 m	7.3	—	5.8	2.1	1.7	1.7	1.8

On June 13. there was H_2S from 20 to 50 m and at 80 m. At 60 m and 70 m there were small amounts of oxygen, the saturation percentages being 0.40 and 0.14 respectively.

This particular distribution of oxygen is due to a partial renewal of the bottom water, which took place in the early spring of 1941. As mentioned above (pag. 21), the bottom water in the outer fjord had then been renewed, and some of the intruding aerated water also passed the threshold at Bønes and poured into the deep basin of Marmorøya. The old bottom water was then lifted up. But the inflowing current was week, and on its way through the outer basins the water had given off so much of its oxygen, that it was not able to oxidize all the H_2S in the water below 20 m near Marmorøya. There remained an intermediate layer, which was lifted up, and by degrees carried away by the tide currents. On its way out this layer was then partly oxidized, and we find it again in the outer fjord in 15 m depth. Such conditions are also mentioned by Gaarder (1916). Further in, at Kråkenes (st. 2), no renewal of the bottom water took place in the spring of 1941.

From June to December 1941 H_2S was found in all parts of the inner fjord in the water layer below 20 m. On several occasions oxygen and H_2S were observed simultaneously at the upper border of the bottom water layer. The water samples had a distinct smell

of H_2S but, when titrated in the ordinary way, showed small amounts of oxygen. Similar conditions are recorded by Gaarder (1916).

The renewal of the bottom water in the early spring of 1942 was so complete, that all the H_2S was oxidized. On April 10. observations were taken through the ice at Paradisholmen. The saturation percentages of oxygen at the different levels were as follows:

Depth, m.	1	2½	5	10	15	20	25	30	40
Oxygen, % sat.	86.4	81.6	60.9	30.3	37.1	39.4	39.7	41.9	42.7

The fact that there was a minimum percentage in 10 m and increasing values from 10 to the bottom indicated that an influx of new water, rich in oxygen, probably still was taking place. This minimum layer could be traced until the middle of May, when it had been limited to a small layer in 15—20 m depth, due to the vertical circulation in the surface layer.

The oxygen content in the water below 20 m decrease rapidly, and in the middle of July the sample from 40 m level contained H_2S. At 25 m small amounts of oxygen (0.08 ml/l) were still found on September 18.

At Marmorøya the layer below 20 m contained more than 3 ml oxygen per liter at the end of April, with a percentage of saturation of about 40. On April 21. the distribution of oxygen was as follows:

Depth, m.	1	2½	5	10	15	20	25	30	40	50	70	80
Oxygen, % sat.	97.7	89.2	84.8	38.0	36.7	40.0	43.3	43.3	46.1	44.5	41.6	41.4

There was a minimum percentage at 15 m, the values increasing somewhat to 40 m. From 40 m to the bottom the percentage again decreased, indicating that the renewal had taken place some time ago. The intermediate minimum could be traced until June 23. After that date it disappeared, and the oxygen percentage decreased from 10 m to the bottom. On July 8. the following values were found:

Depth, m.	12	15	25	50	80
Oxygen, % sat.	91.0	28.9	17.4	15.3	1.5

On September 18. still no H_2S was found. The distribution of oxygen was as follows:

Depth, m.	5	12	15	25	50	80
Oxygen, % sat.	90.0	36.5	6.1	6.0	6.0	1.4

In the spring of 1942 the upper 10 m was rich in oxygen. On April 29. 10.79 ml/l were found at 1 m level, with a saturation of 152.4 %. The respective values at 2½ m were 10.64 ml/l and 146.2 %.

The Plankton Fauna of the Nordåsvatn 1941-42.

Of the different groups of plankton organisms the copepods nearly always play the greatest part, and I have therefore dealt with them most thoroughly. But the other groups have also been included in the counts in order to obtain an impression of the composition of the zooplankton population.

Fluctuations in number.

In fig. 12 the variation in the total number of organisms in the Nordåsvatn in 1941—42 is shown. In the i n n e r f j o r d they number 2000—10000 per total haul from bottom to surface in May 1941

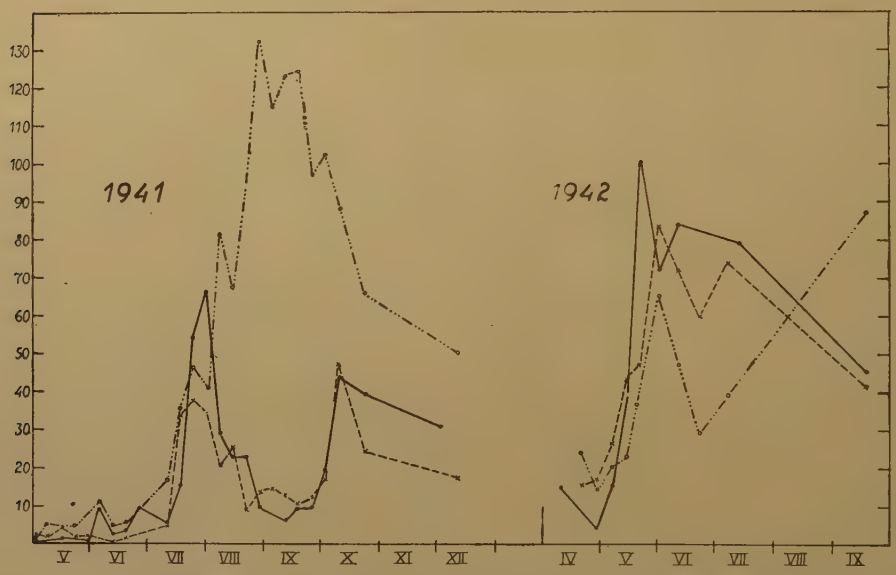

Fig. 12. Number of organisms in 1941—42 in 1000's.
——— Paradisholmen, x- - - -x Marmorøya, o— . . . —o Bønes.

and do not vary essentially until the middle of July. We then have a rapid rise to a maximum at the beginning of August, a decrease throughout August to a minimum in September, a second maximum in the middle of October and somewhat lower numbers in December.

In the o u t e r f j o r d the variation is similar to that of the inner fjord from May to the end of July. Later on the number continues to increase, reaching maximum at the end of August. This

maximum number is twice as great as the August maximum in the inner fjord. From the middle of September the number is steadily decreasing until December, but all the time being much greater than those of the inner fjord.

At the beginning of April 1942 the numbers are low all over the fjord and they decrease further towards the end of the month. Throughout May they are increasing to a maximum at the beginning of June. (At Paradisholmen in the latter half of May). At Marmorøya there is a second maximum in July, in the outer fjord a minimum in June. In September the numbers are lower in the inner fjord, higher in the outer part.

The composition of the plankton fauna.

In order to show the variations in the composition of the zooplankton in the Nordåsvatn, I have set forth the relative percentages of the various groups of plankton organisms in 1941—42 in table 1. The group «Benthonic evertebrate larvæ» comprises larvæ of mussels, gasteropods, ascidians, echinoderms, polychætes, cirripedians, decapods and bryozoa. «Other organisms» include medusæ, fish eggs and larvæ, and unidentified forms.

The mean percentage values for 1941—42 are almost equal for the two stations in the i n n e r f j o r d. The copepods are of greatest importance, amounting to 68—70 % of the total number. But the neritic character of the plankton is shown, apart from the neritic copepods, also by the high percentage (11—13 %) of meropelagic forms, cladocera and benthonic evertebrate larvæ. The copelata range 3rd with 3—7 %. In the o u t e r f j o r d the copepoda form a greater part, with 82 %. The other groups follow in the same succession as in the inner part, but are less predominant.

In the course of the year the zooplankton varies considerably in its composition.

The c o p e p o d s are nearly always predominant, except in the inner fjord in June and July 1941, when they are outnumbered by the cladocera. In October the copepod percentage is also comparatively low. In 1942 the copepods on the whole form a greater part of the zooplankton than in 1941.

The c l a d o c e r a have their greatest importance in the inner fjord. They are numerous from June to October, with maximum percentage in July 1941 and June 1942, the latter year with the greatest percentage in the outer fjord. In December the cladocera disappear almost totally.

Table 1. The composition of the zooplankton population in the Nordåsvatn May 1941 — September 1942. Relative percentages of the various groups.

Year	1941							1942					
Month	May	June	July	Aug.	Sep.	Oct.	Dec.	Apr.	May	June	July	Sep.	Mean
	Paradisholmen												
Copepoda	64.2	28.6	40.3	72.2	70.0	50.0	90.0	78.8	80.5	79.0	96.0	87.3	69.8
Cladocera	0.2	34.8	45.4	16.2	0.1	33.3	T	0.3	5.3	15.4	1.4	0.9	12.8
Copelata	6.0	1.7	6.7	1.3	1.5	8.8	3.5	9.3	7.0	T	—	1.2	4.0
Chætognatha	—	—	—	T	T	T	0.3	0.4	0.3	0.2	0.1	0.05	0.1
Benth. ev. larvæ	29.2	34.2	7.5	9.2	19.7	7.8	4.9	10.7	6.5	5.1	2.3	10.5	12.4
Other organisms	0.3	0.7	0.1	0.1	8.7	0.1	0.5	0.6	0.4	0.2	0.2	0.05	1.1
	Marmorøya												
Copepoda	52.3	33.8	35.6	70.1	70.1	53.0	82.8	81.4	77.1	80.0	88.5	95.2	68.3
Cladocera	0.6	17.1	50.8	14.4	1.0	24.1	0.2	0.6	4.0	14.7	8.8	0.4	11.4
Copelata	10.8	21.0	7.8	2.4	3.1	11.1	7.5	5.1	11.2	0.3	0.2	1.6	6.8
Chætognatha	—	—	T	T	T	T	0.2	0.6	1.4	0.4	0.3	0.4	0.3
Benth. ev. larvæ	36.0	10.1	5.7	12.5	23.6	11.4	9.3	10.9	5.1	4.0	1.8	2.2	11.1
Other organisms	0.3	17.9	0.1	0.6	2.2	0.4	0.1	1.5	1.1	0.6	0.4	0.1	2.1
	Bønes												
Copepoda	71.2	70.5	70 5	94.7	95.7	82.0	94.1	82.5	67.2	72.2	85.5	95.3	81.8
Cladocera	2.0	3.6	23.5	1.2	0.7	7.6	T	0.2	8.8	20.8	6.8	0.2	6.3
Copelata	1.9	4.0	2.2	1.0	0.7	4.8	2.2	2.2	13.8	0.6	0.3	0.2	2.8
Chætognatha	T	0.2	0.2	0.7	0.9	0.9	0.3	1.1	3.0	1.9	1.6	0.3	0.9
Benth. ev. larvæ	23.0	19.2	3.4	2.2	1.7	4.5	3.3	12.4	5.7	3.9	5.2	3 9	7.4
Other organisms	1.8	2.5	0.2	0.1	0.3	0.2	0.1	1.5	1.5	0.6	0.6	0.1	0.8

The copelata have also their greatest importance in the inner fjord during 1941, but the fluctuations are smaller than for the cladocera. The greatest percentages (6—9 %) occurred in May—July and October. In 1942 maximum percentages were found in May, with greatest value, 13.8 %, in the outer fjord.

The chætognatha on the whole are of little significance during 1941, and are mostly confined to the outer fjord.

In 1942, however, the percentages are greater, and the chætognatha also occur numerously in the inner fjord.

Benthonic evertebrate larvæ form an important part of the zooplankton, especially in the inner fjord, and are present all the year. They obtain their greatest percentages in May—June and October 1941 and April 1942.

The group «Other organisms» is of little importance, except at Marmorøya in June and Paradisholmen in September 1941, the high percentages at both places being caused by a greater number of eggs and larvæ of *Pleurobrachia pileus*.

The distribution of organisms in the Nordåsvatn in relation to the hydrographic conditions.

As mentioned above (page 10) the Nordåsvatn is a land-locked water. The deeper water layers are regularly free of oxygen and contain H_2S. The border between the surface layer and the bottom layer is very distinct in the inner fjord, situated between 12 and 15 m. In the outer fjord the deeper water layers often contain more or less oxygen right to the bottom.

Such conditions affect the plankton population to a high degree. Organisms that belong to the deeper water layers, are excluded from the inner fjord, but may to a minor extent thrive and survive in the outer basins. Only those organisms that belong to the surface layer, can live for a longer period in the inner fjord. The copepod fauna of the Nordåsvatn is very poor in species compared with that of the fjords outside. (Cfr. Runnstrøm 1932). Most of the species which usually occur in deeper waters, are lacking, or, when present, are found in very small quantities. The relative percentages of the various species are also different from those of open fjords, (Ruud 1929,

Wiborg 1940). In the Nordåsvatn, *Calanus finnmarchicus* is of little importance, whereas the small cyclopoid copepod *Oithona helgolandica* on an average is the most numerous plankton animal.

In 1941, the zooplankton population in the inner fjord both quantitatively and qualitatively differed from that of the outer fjord. *Pseudocalanus minutus* e.g. was both in number and in relation to the other copepods of much more importance in the outer than in the inner fjord. *Oncæa borealis* and *Microcalanus pygmæus* were confined to the outer part of the Nordåsvatn, and this was also the case with *Sagitta elegans.*

In 1942, with the total renewal of the deeper water layers, an entirely new stock of copepods and other plankton organisms was introduced from the fjords outside the Nordåsvatn. In the deeper water layers we now find *Calanus hyperboreus, Metridia longa,* a greater number of copepodites and adults of *Calanus finmarchicus,* together with other organisms belonging to these water layers.

As long as the bottom water contains sufficient quantities of oxygen, these organisms can also thrive in the inner fjord. But, by degrees the oxygen is consumed, and then the animals die out and disappear, as they cannot adapt themselves to the hydrographic conditions in the surface layer. This was clearly seen during 1942. In 1941 *Microcalanus pygmæus* e.g. occurred in small numbers in the deeper water layers of the outer fjord. In April 1942 it was found at all stations, but it disappeared from the inmost station May 22, from the Marmorøya station June 2. *Calanus hyperboreus* was not present in the Nordåsvatn in 1941, but was introduced in small numbers in 1942. At Paradisholmen this species disappeared May 27, while at Marmorøya and Bønes single individuals still occurred July 8. On September 18. no specimens were found. *Sagitta elegans* was also common in the inner fjord in 1942.

Currents in the surface layer are chiefly caused by the tides, but also by winds, and the prevailing winds in the Nordåsvatn being south-westerly, the surface currents will mainly run in an inward direction. Single plankton animals belonging to the outer fjord are occasionally found in the inner part, e.g. *Sagitta elegans,* mainly the younger individuals, which keep to the surface layer.

The common increase in the zooplankton population from August 11. to 18. may to a certain part be ascribed to the surface current, which carried with it a greater quantity of plankton. The increase was first remarked in the outer fjord.

Some s e w a g e is carried into the Nordåsvatn from a densely peopled area to the north of the fjord, and this may affect the zoo-

plankton population to a certain degree. As mentioned in a previous paper (Wiborg 1940) no copepods have been found which are exclusively saprophile. But there is a certain quantitative difference in the zooplankton populations at the inmost station and at the Marmorøya station (see table 3, page 33). In 1941, the copepods *Oithona helgolandica, Oncæa subtilis* and *Paracalanus parvus* attained their greatest average percentages at the Paradisholmen station, while the other copepods had increasing percentages from this station to Marmorøya. Whether this is caused by a contamination of the water in the northern part of the Nordåsvatn, or there are other causes for the distribution of the copepods, cannot be stated with certainty.

The Copepod Fauna of the Nordåsvatn 1941-42.

The copepods are nearly always the most important group of zooplankton organisms, and this is also the case in the Nordåsvatn.

The variation in total number of the copepods in 1941—42 is shown in fig. 13. It will be seen that the curve is quite similar to that of the total number of organisms.

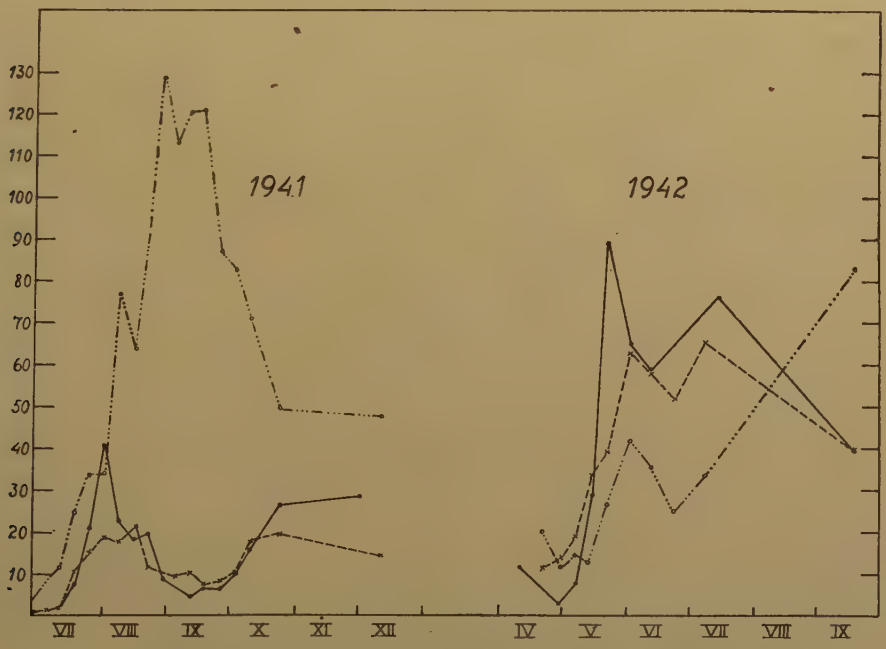

Fig. 13. Number of copepods in 1941—42 in 1000's.
———— Paradisholmen, x- - - - -x Marmorøya, o . . . — . . . o Bønes.

In 1941 there was a small stock of copepods (2000—3000) in the inner fjord from May till July 11, when numbers began to rise. Maximum occurred in the first half of August, minimum in September, a second maximum in October, and still high numbers in December. The curve for the outer fjord follows that of the inner fjord till August 1, but later it continues to rise till August 29. The bulk of the copepod stock then consists of *Oithona helgolandica* and *Pseudocalanus minutus* in about equal amounts. Together these two copepods form 90 % of the total number of organisms. High figures prevail till September 18. Later, the number is decreasing, but it is all the time much higher than that of the inner fjord.

In 1942, conditions were quite different from those of 1941. In the middle of April the stocks are comparatively high in all parts of the Nordåsvatn, they decrease to a minimum at the end of the month, and again increase to a maximum at the end of May. In the middle of June there is a second minimum, later an a general increase to the middle of July. A high number was found in the outer fjord on September 18.

The composition of the copepod stock.

In 1941—42 there occurred in the Nordåsvatn 16 species of calanoids, 5—6 of cyclopoids and at least 14 species of harpacticoids. But only few species, viz. 6 of calanoids and 2 of cyclopoids, were found regularly and in larger numbers.

In table 2 the relative percentages of the most important copepods occurring in the Nordåsvatn during 1941 and 1942 are set forth.

In considering the average percentages we find a distinct difference in the composition of the copepods during the two years. In 1941 the *Oithona spp.* rank first in percentage. Next come *Pseudocalanus* and *Acartia*. In 1942, the *Oithona* again have the greatest percentage, but now the *Temora* ranks second and *Calanus finmarchicus* third in percentage. This difference is to a great extent caused by the total renewal of the deeper water layers in the early spring of 1942. The incoming water brought with it a new stock of copepods.

The individual species of copepods vary in percentage during the year.

Calanus finmarchicus was of little significance in 1941, but in April and May 1942 it constituted 29.2 % and 10.2 % of the copepod stock, respectively. Later on it gradually diminished in importance.

Table 2. The percentage composition of the copepod stock in the Nordåsvatn 1941—42.

	1941								1942					
	May	June	July	Aug.	Sep.	Oct.	Dec.	Mean	Apr.	May	June	July	Sep.	Mean
Calanus finmarchicus	0.3	0.1	0.4	0.5	0.5	0.7	0.2	0.4	29.2	10.2	1.7	0.6	0.2	8.4
Pseudocalanus minutus	11.3	18.0	11.3	15.6	18.3	15.7	2.6	13.3	5.5	11.3	7.3	5.3	8.5	7.6
Centropages hamatus	0.3	0.3	1.3	0.7	T	0.3	0.1	0.4	0.3	0.4	1.1	0.6	0.1	0.5
Temora longicornis	3.5	8.0	10.7	6.3	0.8	1.6	0.3	4.5	13.9	16.5	28.0	11.8	0.8	14.2
Acartia spp.	20.5	7.6	10.5	3.6	0.5	3.0	1.1	6.7	2.1	7.7	5.5	6.7	0.5	4.5
Paracalanus parvus	0.8	0.3	4.4	6.4	3.6	30.5	33.2	11.3	5.2	1.8	0.3	0.1	2.0	1.8
Oithona spp. [1]	61.8	57.8	57.7	64.2	73.0	45.6	60.7	60.1	30.7	46.8	53.5	71.5	78.1	56.2
Oncœa spp. [2]	1.0	3.0	1.7	1.5	2.1	1.6	1.7	1.8	11.4	4.2	2.3	3.2	9.5	6.1
Other copepods	0.5	4.9	2.0	1.2	1.1	1.0	T	1.5	1.7	1.1	0.3	0.2	0.2	0.7

[1]) Mainly *O. helgolandica*, [2]) Mainly *O. subtilis*.

Table 3. The average percentage composition of the copepod stock at 3 localities in the Nordåsvatn 1941—42.

	1941			1942		
	Paradisholmen	Marmorøya	Bønes	Paradisholmen	Marmorøya	Bønes
Calanus finmarchicus	0.4	0.4	0.3	6.1	14.6	4.4
Pseudocalanus minutus	1.5	5.3	33.0	4.4	8.8	9.6
Centropages hamatus	0.3	0.4	0.5	0.3	0.5	0.7
Temora longicornis	1.8	4.7	6.9	10.0	12.3	20.3
Acartia spp.	2.6	6.7	10.8	2.2	3.8	7.5
Paracalanus parvus	16.8	13.2	3.9	1.8	1.4	2.4
Oithona spp.	71.8	65.4	43.1	72.3	53.3	42.8
Oncœa spp.	2.3	2.2	0.9	2.8	4.6	11.0
Other copepods	2.4	1.6	0.6	0.1	0.7	1.3

Pseudocalanus minutus varied between 11 and 18 %, except in December 1941, when the percentage was only 2.6. The values for 1942 were lower than those for 1941.

Centropages hamatus was both years of little importance, with percentages from 0.1 to 1.3.

Temora longicornis varied greatly in its appearance. It was an important factor in the plankton from April to August 1941, with a maximum percentage of 10.7 in July and 28.0 in June 1942.

Of the *Acartia* species, *A. longiremis* was of most importance. It had its best time from May to June both years, in May 1941 constituting more than 20 per cent of the stock of copepods. In the autumn and winter it was scarce and to some degree substituted by. *A. clausi*, which, however, never became so numerous.

Paracalanus parvus is a typical autumn form, which in October and December 1941 made 30—33 % of the copepod population. On other occasions it was comparatively scarce.

Numerically, *Oithona helgolandica* is always the most important copepod, as a rule constituting over 50 %, up to 78 % of the stock of copepods. *Oithona nana* was never numerous, *O. spinirostris* very scarce.

Oncæa subtilis has not previously been recorded from Norway. The percentage varied between 1 and 3 during 1941. In 1942, the values were greater, in April 11.4 %, decreasing somewhat till June, but again increasing in September. *Oncæa borealis* was always scarce, in 1941 confined to the outer fjord.

The average percentages of the most important copepods at 3 localities in the Nordåsvatn during 1941 and 1942 are shown in table 3.

In 1941, *Paracalanus, Oithona helgolandica* and *Oncæa subtilis* were of greatest importance in the inner fjord, while *Pseudocalanus, Temora* and *Acartia* were most common in the outer part. The percentages of all these species are gradually changing from Paradisholmen through Marmorøya to the Bønes station.

In 1942, *Calanus finmarchicus* hat its greatest percentage at Marmorøya, caused by a greater number of individuals in the deeper water layers. The other copepods had the same regional distribution as that of 1941, with the exception of *Oncæa subtilis*, which was now most numerous in the outer fjord.

The different species of copepods.

Calanus finmarchicus (Gunnerus).

Previous investigations on this copepod are very extensive, and will not be quoted here. For litterature I refer to a previous work (Wiborg 1940).

In 1941, *Calanus finmarchicus* was of little importance in the Nordåsvatn, but in the first half of 1942 it was quite numerous. The numerical variations in these years are shown in fig. 14.

In May—June 1941 the numbers were negligible in the inner fjord. In July there was an increase, in August a maximum, a minimum in September, a second maximum in October and a minimum in December. In the outer fjord we have a steady increase from July to a maximum in October, then a decrease to December. The numbers on the whole were greater in the outer than in the inner fjord.

At the beginning of April 1942 a fairly large stock of *Cal. finm.*

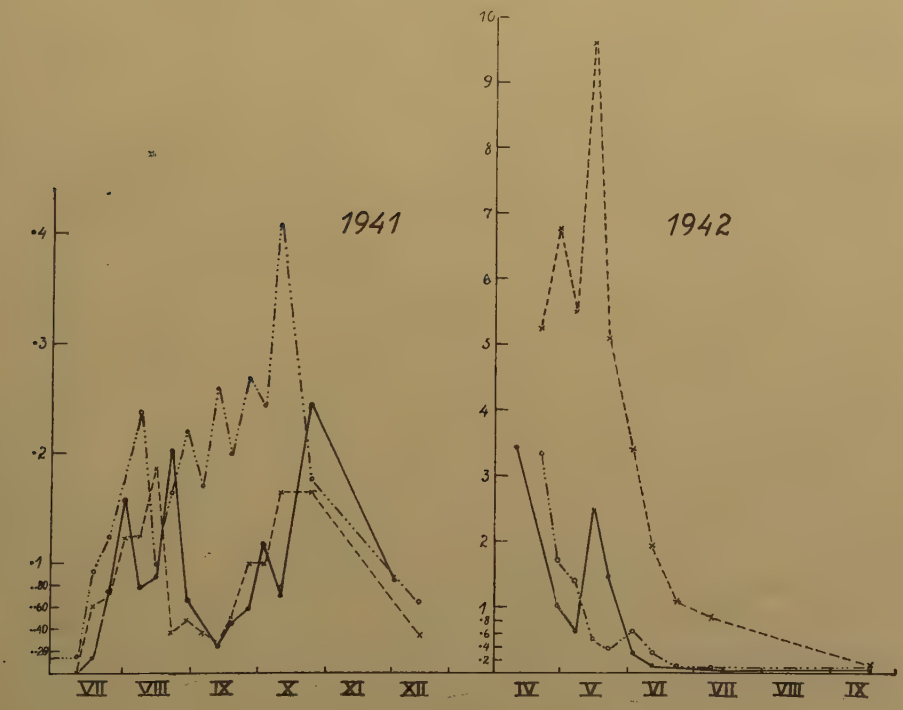

Fig. 14. Number of *Calanus finmarchicus* in 1941—42 in 1000's.
———— Paradisholmen, x-----x Marmorøya, o . . . — . . . o Bønes.

was found, carried in from the fjord outside the Nordåsvatn simultaneously with the renewal of the deeper water layers. With the exception of a small increase in the inner fjord from May 7. till 15. there was a steady decrease in numbers from April to September. During 1942, the largest stock was always found at Marmorøya, owing to a great number of elder copepodites in the deeper water layers.

Distribution of stages.

The relative percentages of all stages of *Cal. finm.* have been worked out for each half-month from July 18. 1941 to September 18. 1942 (table 7. at the end of this paper). Representatives of the stage distribution are shown in fig. 15.

1941. The nauplii are dominating nearly all the time and form a maximum in September. In the inner fjord the other stages have an irregular distribution and are of negligible importance except in December, when stage V has a maximum percentage. In the outer fjord the percentage of nauplii is on an average smaller than in the inner part from July to September, and there is a secondary maximum of females with copepodite stages V—III following closely. In October a maximum is formed by stage V, in December by the females and nauplii.

1942. An entirely new stock has been introduced. A maximum of nauplii in the first half of April is followed successively by maxima of the different copepodite stages, last of stage V in the latter half of May. In the inner fjord this maximum is maintained till the middle of July and is again found in September. This is also the case with a secondary maximum of nauplii, whereas the nauplii form the primary maximum at Bønes, followed by a secondary maximum of females in September.

In 1941, it is difficult to trace the different spawning periods. Apparently there is continuous spawning from July to October, most intensive in August—September. In winter *Cal. finm.* seems to die out almost entirely.

In the winter and early spring of 1942 a new stock is introduced from the fjord outside the Nordåsvatn, mainly as nauplii.

In the spring of 1942 the development from the last nauplius stage to the third copepodite stage lasted about a fortnight, and the same period was occupied for the development from stage III to IV and from IV to V.

In the outer fjord a new spawning probably took place in September 1942.

The hydrographic conditions in the Nordåsvatn commonly are not well suited for *Calanus finmarchicus*, and a greater stock is only found when the deeper waters have been renewed.

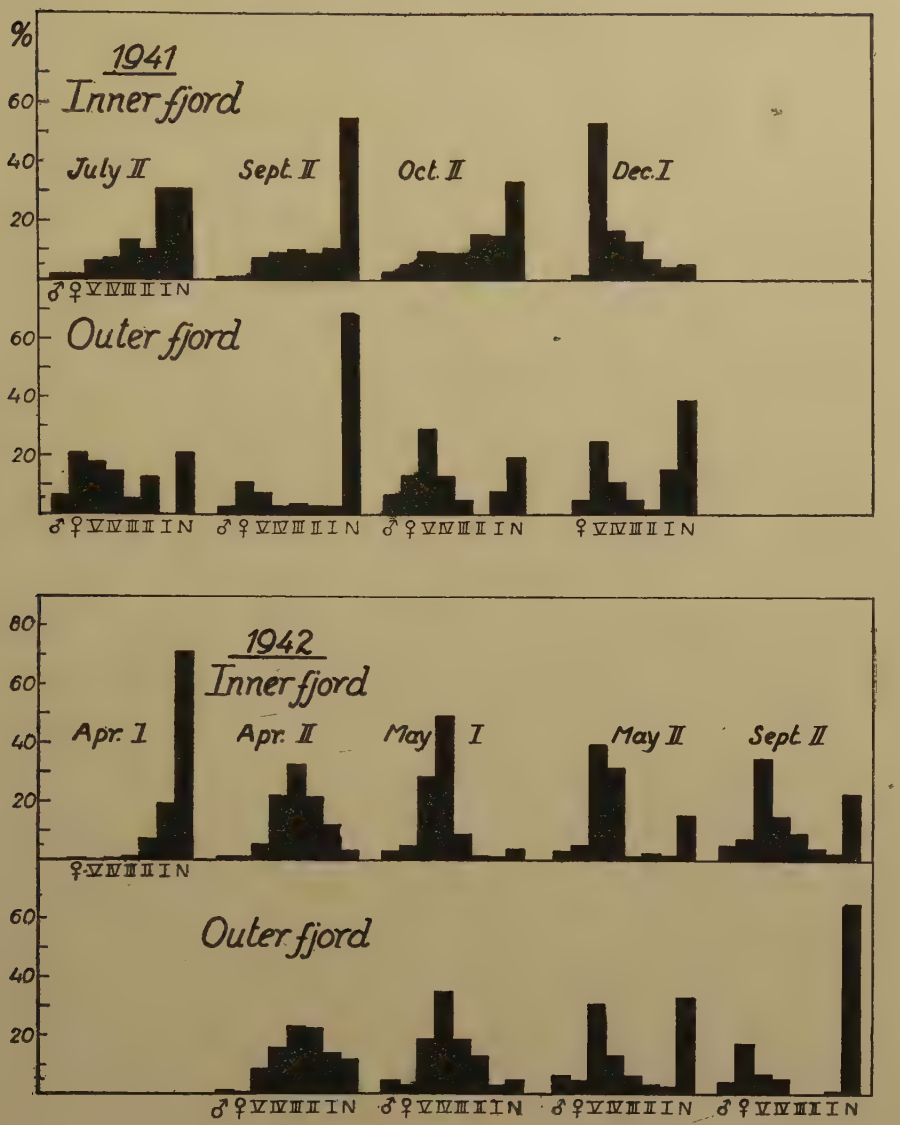

Fig. 15. Percentage distribution of each stage of *Calanus finmarchicus* in 1941—42.

The individuals were always small, with exception of single specimens of copepodite stage V in the deepest hauls at Marmorøya.

Vertical distribution.

The plankton hauls were made in daytime only. In 1941 the bottom water of the inner fjord contained H_2S from 20—25 m level and downwards.

The vertical distribution of the different stages of *Calanus finmarchicus* in July—December 1941 is shown in tables 4 and 5. In the inner fjord (table 4) the greater part of all stages in July—August frequented the 15—0 m layer. At Paradisholmen, however, a great percentage of females and copepodites of stage V—IV was taken below 15 m. After August 15. the vertical hauls were divided according to the different water layers. A greater part of all stages was then caught in the 20—12 m haul. We may therefore assume that in summer the bulk of all stages of *Calanus finm.* frequents the transition layer between 12 and 15 m.

Table 4. The percentage distribution of each stage of Calanus finmarchicus in the various hauls in the inner fjord in 1941.

Stage	Paradisholmen July 18th—Aug. 8th		Marmorøya July 18th—Aug. 8th		Paradisholmen Aug. 15th—Dec. 12th		Marmorøya Aug. 15th—Dec. 12th	
	15 ↑ 20	0 ↑ 15	15 ↑ 20	0 ↑ 15	12 ↑ 20	0 ↑ 12	12 ↑ 20	0 ↑ 12
♂	13	87	25	75	90	10	63	37
♀	57	43	33	67	86	14	77	23
V	43	57	9	91	87	13	67	33
IV	32	68	2	98	84	16	61	39
III	26	74	—	100	86	14	67	33
II	11	89	—	100	75	25	76	24
I	7	93	—	100	65	35	70	30
N	21	79	—	100	44	56	53	47

In the outer fjord (table 5) we find a greater percentage of all stages in the upper 15 m in the periods July 25. to August 15, and September 26. to December 12. The adults and in part cop. stage V have a somehwat greater concentration in the 30—15 m layer. The percentage of copepodites in this layer is decreasing from stage V to I. Below the 30 m level we find some adults and copepodites of stage V, also a small percentage of stage IV—III.

In the period August 28. to September 18. most part of all stages is concentrated in the 30—15 m layer, and a great part of copepodite stage V keeps below 30 m.

In 1942, the vertical hauls at Marmorøya were divided into 4 steps (fig. 16). Three periods are distinguished, namely, April 21. to May 7. (1.), May 15.—22. (2.) and June 6. to July 8. (3.).

Table 5. The percentage distribution of each stage of Calanus finmarchicus in the various hauls at Bønes 1941.

Stage	July 25th—Aug. 15th			Aug. 28th—Sep. 18th			Sep. 26th—Des. 12th		
	30↑50	15↑30	0↑15	30↑50	15↑30	0↑15	30↑50	15↑30	0↑15
♂	13	44	43	17	83	—	7	40	53
♀	8	64	28	27	72	1	20	42	38
V	14	42	44	42	57	1	18	55	27
IV	—	30	70	8	92	—	7	36	57
III	—	10	90	3	97	—	1	13	86
II	—	5	95	—	100	—	—	6	94
I	—	—	100	—	97	3	—	1	99
N	1	6	93	—	97	3	—	5	95

The adults at first are only found below 40 m, but from June 6. there is a rising movement, and after June 12. we find almost the entire stock above 40 m, with greatest concentration in the upper 15 m. This change in the vertical distribution has probably some connection with the decreasing quantity of oxygen in the water layers below 40 m.

Copepodites of stage IV and V have their greatest percentages below 40 m all the time. These stages are less sensitive to low oxygen concentration than the adults (cfr. Wiborg 1940, pag. 34). Of stage IV a minor part is concentrated in the upper 5 and 15 m in the first and third period, respectively. Copepodites of stage III in the 1. period have a minimum occurrence in the 15—40 m layer, but a greater percentage in the upper 5 m and below 40 m. In the 2. period there is a greater concentration in the 15—40 m layer, and in the 3. period we find nearly all the stock in the upper 15 m.

The stages I and II are sparsely found below 40 m. In the 2. period the major part frequents the 15—40 m layer, but in the other periods these stages keep to the upper 15 m, most concentrated in the upper 5 m. — The nauplii have nearly the same vertical distribution, only with a somewhat greater percentage in the deeper water layers.

The vertical distribution in the outer fjord 1942 is shown in fig. 17. The periods here are: 1) April 21.—29. 2) May 7.—22. 3) June 2. to July 8.

The adults at first are evenly distributed in all water layers, but in the 2. period there is increasing concentration in the deeper layers. In the third period, we find most part of the adults in the upper 25 m.

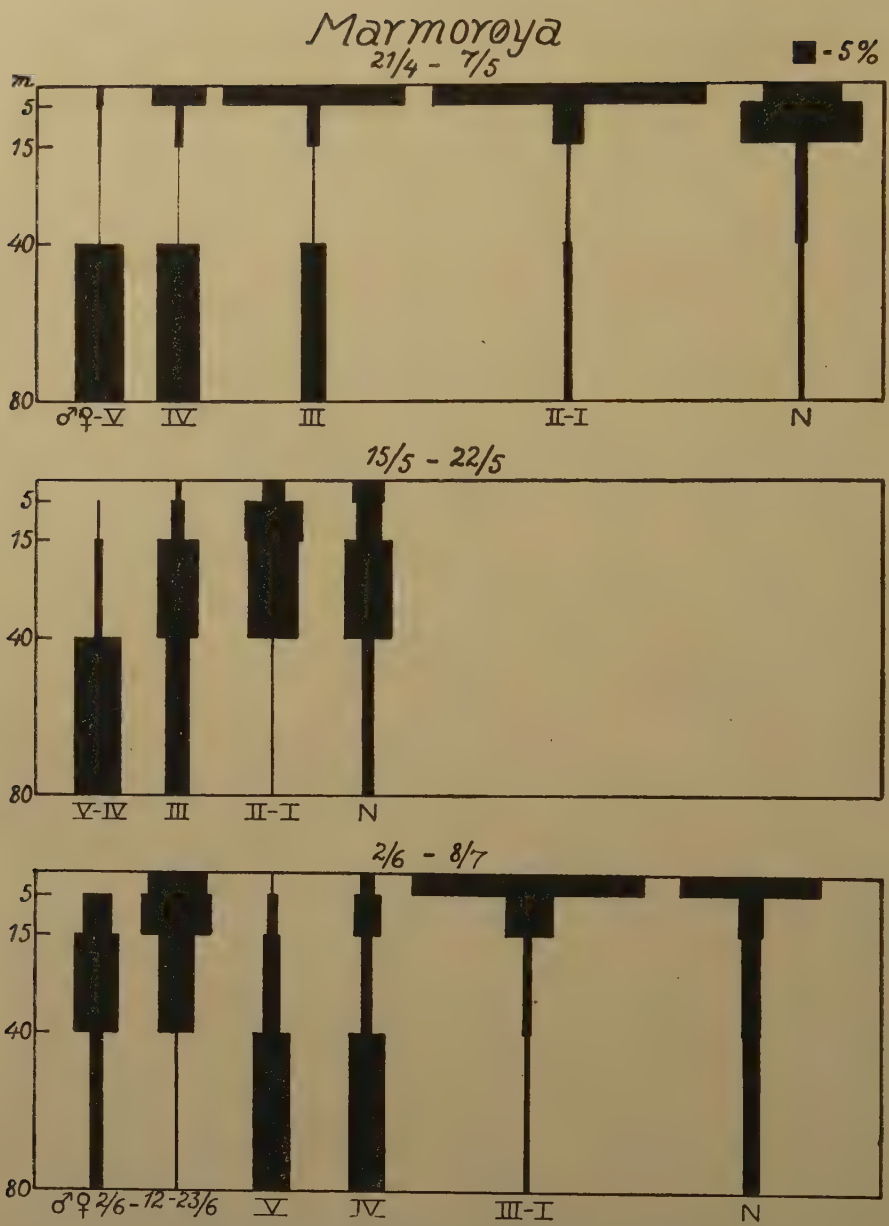

Fig. 16. Vertical distribution of *Calanus finmarchicus* at Marmorøya in 1942. Percentage distribution in the various hauls.

The copepodites of stage V in the 1. period have their greatest percentage in the upper 10 m, decreasing downwards. Later they are evenly distributed in all water layers, and in the 3. period most concentrated below 25 m.

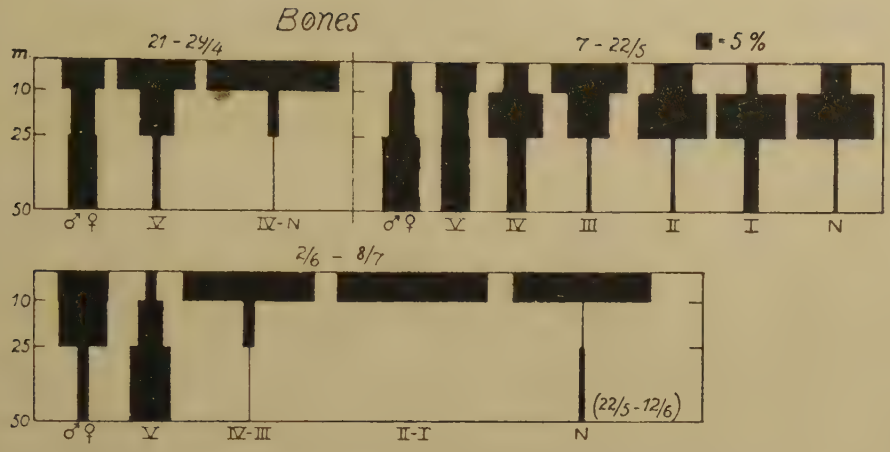

Fig. 17. Vertical distribution of *Calanus finmarchicus* at Bønes in 1942. Percentage distribution in the various hauls.

The copepodites of stages IV—I and the nauplii all show a uniform behaviour. In the first and last period most part of the stocks frequents the upper 10 m. In the second there is a greater percentage in the 20—25 m layer. The copepodites of stage III have their main distribution in the 10—0 m, whereas the stage IV and I have also a certain percentage below 25 m.

Paracalanus parvus Claus.

According to Runnstrøm (1932) this species has a maximum occurrence in August—October near Bergen. In the Oslo Fjord the main season is from July to October (Wiborg 1940).

In the Nordåsvatn, *Paracalanus* was scarce in the spring and early summer of 1941. From July 11. to December 12. the numerical variation is shown in fig. 18.

In the inner fjord there are two maxima, one smaller in the first half of August, one greater in the middle of October. In the outer fjord the two maxima occur somewhat later, at the end of August and probably at the beginning of November (observations lacking), the stock in December being larger than that of October. In April 1942 the stock of *Paracalanus* makes about 700 specimens at Marmorøya and 1400 at Bønes, decreasing to almost nothing from April to July. In September the stocks have again increased. (Paradisholmen 1335, Marmorøya 470, Bønes 1186 individuals).

The rapid increase in numbers in August 1941 must be ascribed to the special nature of this copepod, with an autumn maximum. Both in August and October the highest numbers occurred at the inmost station.

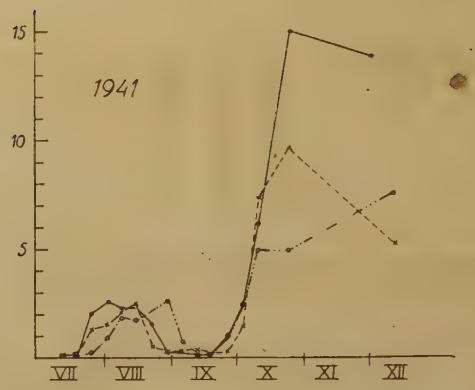

Fig. 18. Number of *Paracalanus parvus* in 1941—42 in 1000's.
———— Paradisholmen, x- - - - -x Marmorøya, o . . . — . . . o Bønes.

In the counts I have separated males, females and copepodites. Only the older copepodite stages are caught, most part of the younger stages and all the nauplii going through the meshes of the net (Wiborg 1940).

As a rule, the copepodites made more than half the stock caught, and in October and December 1941 they made the bulk of it. The females were always more numerous than the males.

We may assume that the percentages of adults vary according to the spawning periods. In order to trace these, I have given the percentages of the males of *Paracalanus* at Paradisholmen and Bønes in the period July—December 1941 in fig. 19.

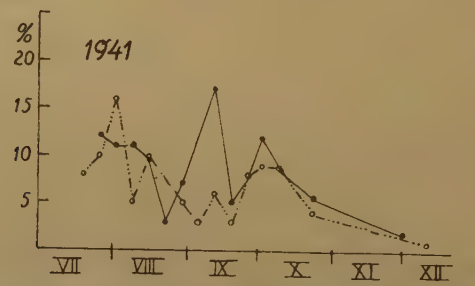

Fig. 19. Percentage distribution of the males of *Paracalanus parvus* July—December 1941. ———— Paradisholmen, o . . . — . . . o Bønes.

At Paradisholmen the curve shows 3 peaks, July 25, September 12. and October 3. At Bønes we find only 2 maxima, August 1. and October 24.

The July maximum of males at Paradisholmen seems to be in accordance with the maximum number of *Paracalanus* in July—

August. A second brood, following the maximum of males in September, has either not taken place, or must have been unsuccesful, since there was no increase in number afterwards, but the third maximum is followed by a maximum number in October.

In the outer fjord, both the maxima of males are followed by maxima in number of individuals.

The period between two maxima is a little more than two months, which agrees well with previous investigations. Propagation probably takes place most part of the year.

Vertical distribution. In 1941, nearly all the *Paracalanus* were taken in the 12—0 m layer, except in the period August 15. to September 5, when the greater part was caught below 12 m. At Bønes, 2/3 of the stock kept in the 30—15 m layer on December 12.

In 1942, conditions were different. At Paradisholmen the major part of the stock was at first taken in the 40—15 m haul, after May 22. however, in the upper 15 m. At Marmorøya the vertical distribution was more even, with maximum occurrence in the 40—15 m layer from April to May. After May 22. the stock below 40 m disappeared, end the maximum number was now taken in the upper 5 m. On September 18. most part of the stock frequented the layer between 12 and 15 m.

At Bønes the greatest number was always found below 25 m, except in September, when 2/3 of the stock were caught in the 15—0 m hauls, 1/3 in the 25—15 m hauls.

Pseudocalanus minutus Krøyer.

According to previous investigations in the waters off Bergen (Runnstrøm 1932) this copepod is moderately numerous all the year, with maximum stock in June—September. Propagation is going on all the year.

The numerical variation of *Pseudocalanus minutus* in the Nordåsvatn in 1941—42 is shown in fig. 20. The curve for the Bønes station in 1941 has to be magnified 10 times.

In 1941, *Pseudocalanus* is scarce in the inner fjord. There are maxima in August and October. In the outer fjord, numbers are great, with maximum in September.

In 1942, *Pseudocalanus* on the whole is more numerous than the previous year. In the inner fjord there are maximum numbers in May, probably in August, in the outer fjord in June and probably in September.

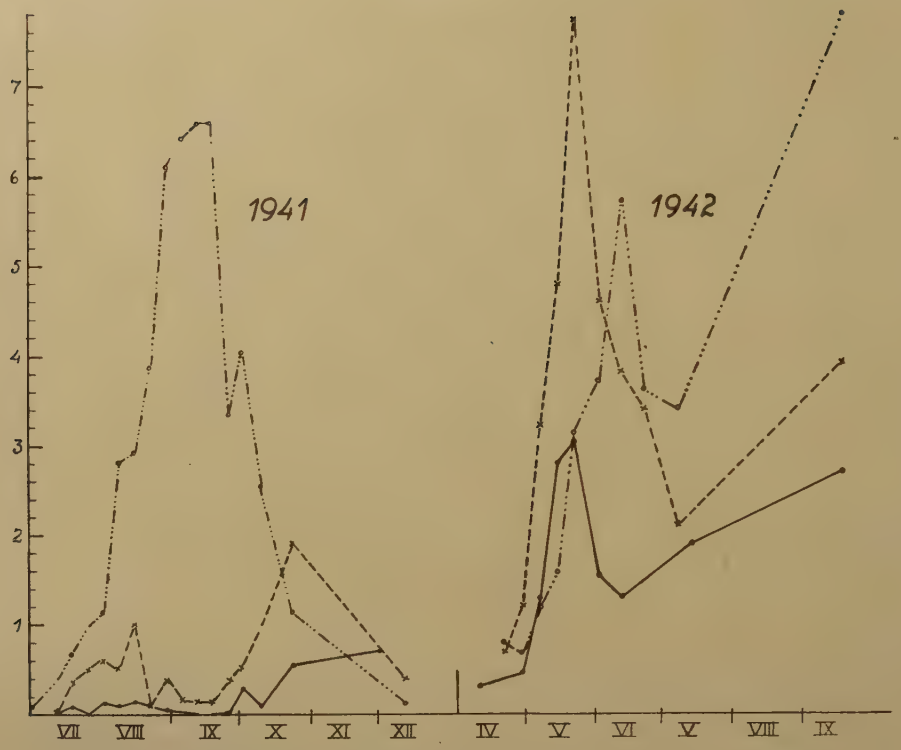

Fig. 20. Number of *Pseudocalanus minutus* in 1941—42 in 1000's.
———— Paradisholmen, x- - - - -x Marmorøya, o . . . — . . . o Bønes.
The curve for the Bønes st. in 1941 has to be magnified 10 times.

Propagation.

Adults, each copepodite stage and nauplii have been counted separately. *Pseudocalanus* is very prolific, and, as a rule, the distribution of stages is very irregular. This is partly caused by the currents in the surface water layers, wich carry the copepodites and nauplii from one place to another.

In order to trace the periods of spawning and the succession of broods, percentage curves have been worked out for all stages at the Marmorøya and Bønes stations during 1941—42. (Fig. 21).

1941. At Marmorøya, the stock before July 18. 1941 is too small to be taken into account. — Males and females are scarce all the year with small maxima of males July 15. and October 24, of females August 15, September 12. and October 24. The copepodites of stages IV and V have maxima in July, August, September and December. — Stage III is comparatively numerous in relation to the other stages. It has irregular variation, with

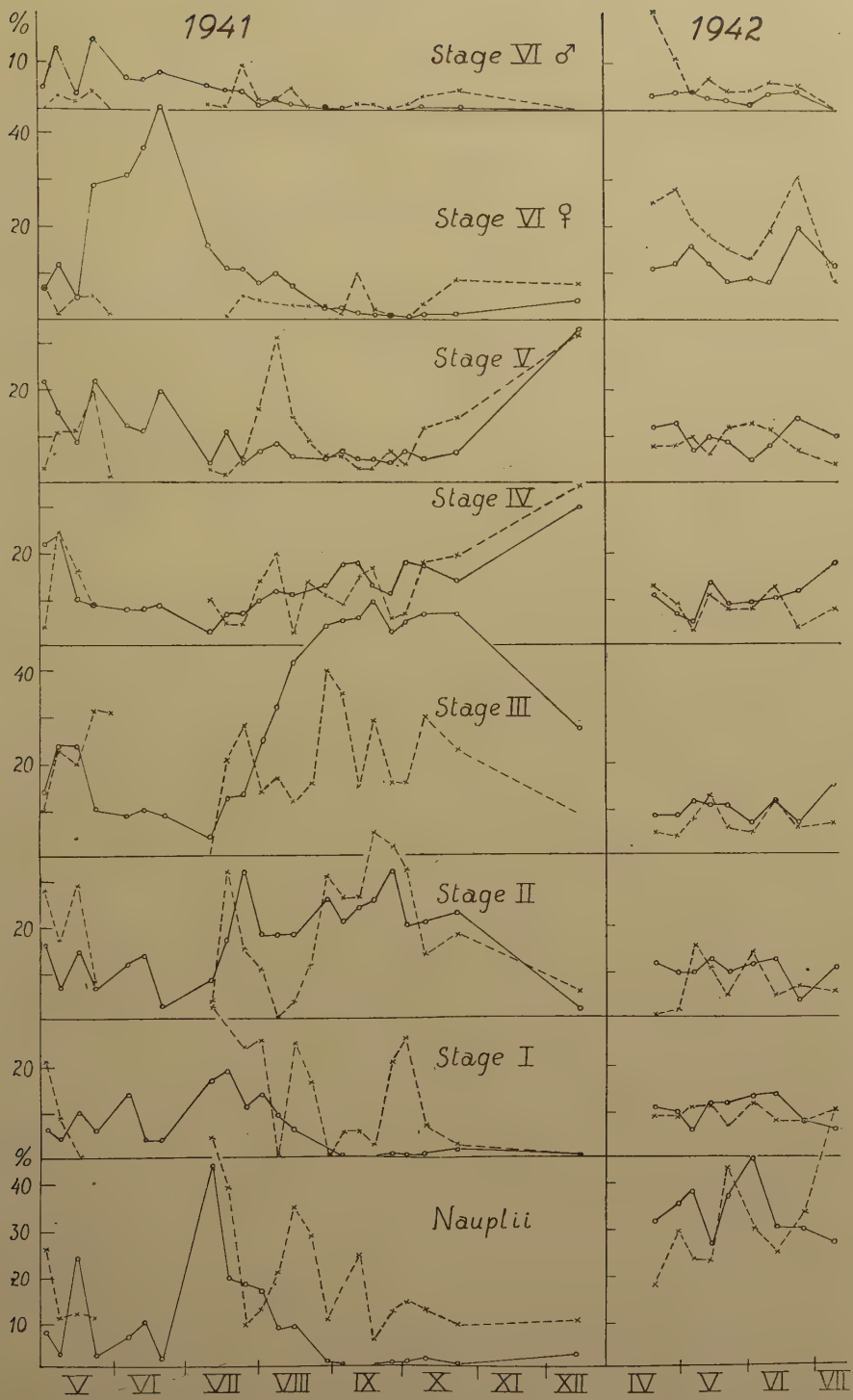

Fig. 21. Percentage distribution of each stage of *Pseudocalanus minutus.* in 1941—42. x- - - - -x Marmorøya, o———o Bønes.

higher maxima at the end of August and the beginning of October. — Stage II is relatively numerous after August 22. with maximum percentage at the end of September. Stage I has its maxima in July, August and October, the nauplii have maxima in July and at the beginning of August, September and October.

At Bønes there is a high percentage of adults, specially females, in May—June, with maximum at the end of June. The copepodites of stages V and IV vary irregularly, with greater percentages in December. — Stage III has a maximum occurrence in the first half of May, later it is scarce until July 25. After that date, the percentage is rising, and from August to December extremely high, this copepodite stage then comprising 40 to 60 % of the total stock of *Pseudocalanus*. — Stage II is very irregular in its variation, with decidedly higher percentages after July 18. — Stage I is of little significance, with a maximum July 18. — The curve for the nauplii shows distinct maxima May 15. and July 18.

In 1942, the distribution of stages is quite different from that of 1941. Adults and nauplii on the whole now form a greater part of the stock.

At Marmorøya, the females show distinct maxima at the end of April and the end of June. The nauplii have 3 maxima, April 29, May 2. and Juli 8. or later. The first maximum can be followed up to copepodite stage IV on May 22. and is followed by the maximum of females on June 23. The second maximum of nauplii is succeeded by the maximum of stage IV on June 12. The third maximum has probably been followed by the maximum of stage III in September.

At Bønes the variation in the distribution of stages is similar to that at Marmorøya, only about a week later in development. The third maximum of nauplii has probably occurred late in July, since there is a maximum of stage II on September 18.

Spawning periods. We must assume that *Pseudocalanus* in the Nordåsvatn is propagating most part of the year. More intense spawning seems to take place in the inner fjord in April, June—July and September—October. Similar periods are indicated in the outer fjord, only somewhat retarded. The main propagation takes place in the autumn. The interval of about two months between each spawning period agrees very well with previous investigations. The secondary maxima of copepodites and nauplii must partly be ascribed to horizontal displacements of the surface water layers, which carry the younger stages from one locality to another. There is also the possibility that the females produce more than one brood, which is previously indicated for other copepods, e.g. *Calanus finmarchicus* (Nicholls 1933).

Vertical distribution.

In 1941 the living plankton in the inner fjord was limited to the upper 20 m. In the period May 2. to August 8. only single

Pseudocalanus were found below 15 m, except on May 23, when the major part of the females and copepodites of stages V, IV, II and I were taken in the 15—20 m haul. From August 15. to September 8. nearly the entire stock was taken in the 20—12 m haul. We must therefore assume that in summer the *Pseudocalanus* remain in the narrow water layer from 12 to 15 m. From September 26. to October 24. there is an increasing percentage of all stages in the upper 12 m. In December they have again moved below 12 m.

In the o u t e r f j o r d, the major part of the stock from June 8. to 20. keeps to the water layer below 20 m, from July 11. to 18. in the upper 15—20 m.

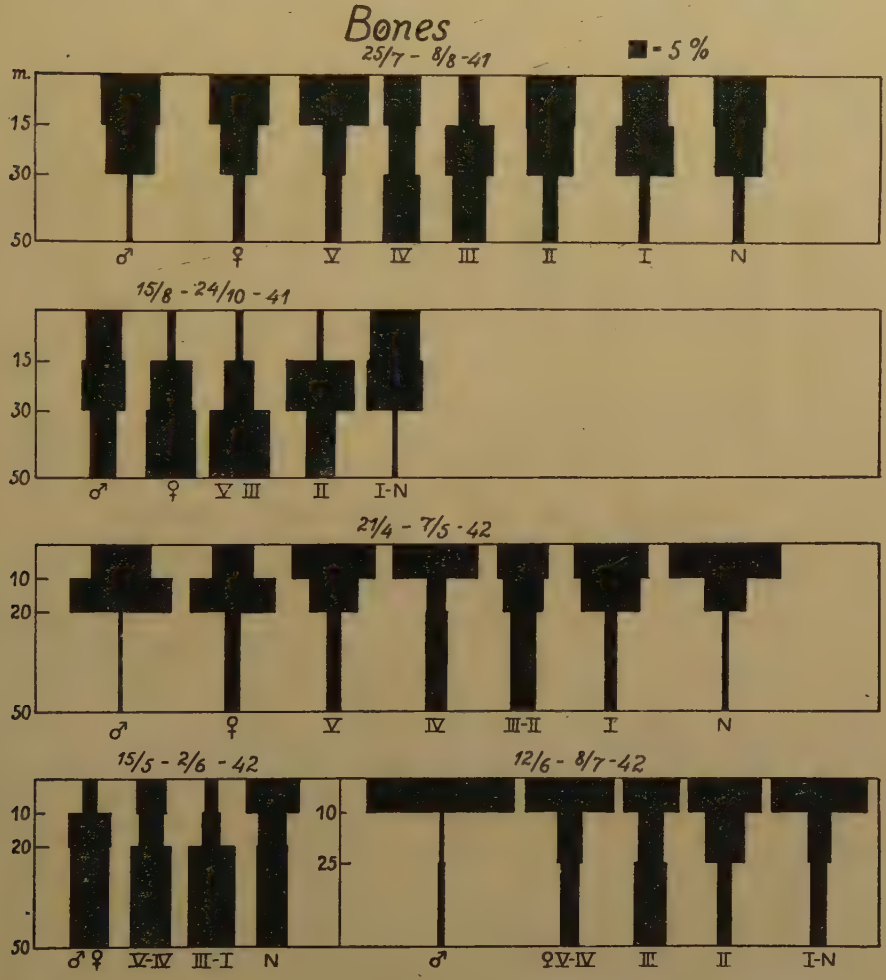

Fig. 22. Vertical distribution of *Pseudocalanus minutus* at Bønes. Percentage distribution in the various hauls.

The vertical distribution in the periods July 25. to August 8, August 15. to October 24, and for the year 1942 is shown in fig. 22.

In the first period copepodites of stages IV and III are almost evenly distributed in all water layers. The remaining stages keep to the upper 30 m, with maximum occurrence of females and copepodite stage V in the upper 15 m. In the second period most part of all stages, except stage I and nauplii, keeps below 15 m. Males and copepodite stage II have their greatest concentration in the 30—15 m layer, females and stage III in the 30—50 m. In 1942 a greater percentage of the *Pseudocalanus* keeps to the upper 20 m, except from May 15. to June 2, when all stages, with exception of the nauplii, are taken in the 50—20 m haul.

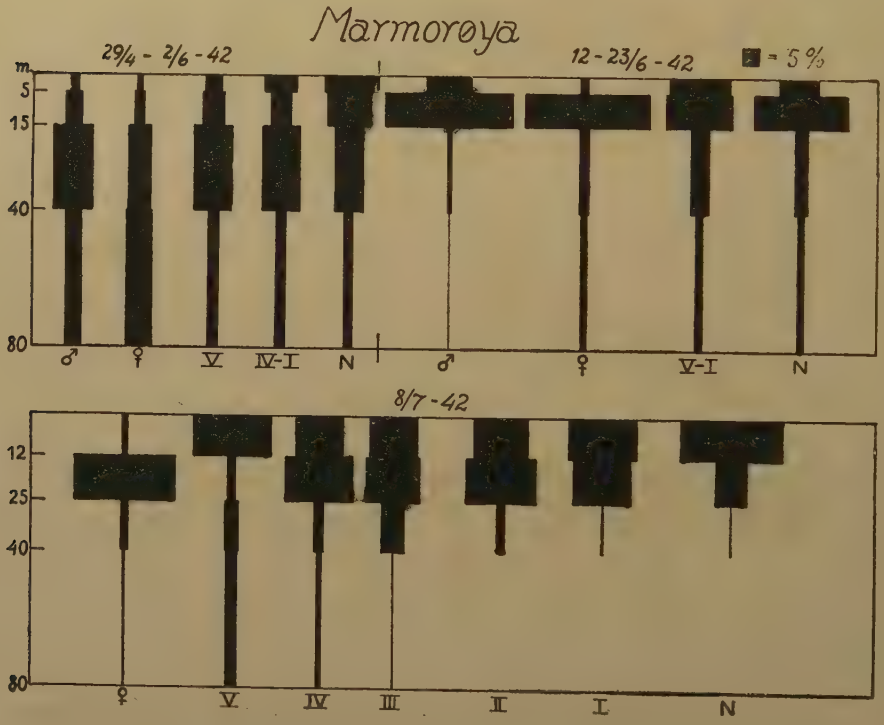

Fig. 23. Vertical distribution of *Pseudocalanus minutus* at Marmorøya. Percentage distribution in the various hauls.

At Marmorøya (fig. 23) a greater part of all stages frequents the 40—15 m layer from April 29. to June 2. 1942, the females being evenly distributed in all water layers down to 80 m. After June 12. we find most part of the stock in the upper 15 (25) m.

Centropages hamatus Lilljeborg.

According to Runnstrøm (1932) this copepod is common near Bergen (Herdla- and Hjeltefjord) from May to October, with maximum in August.

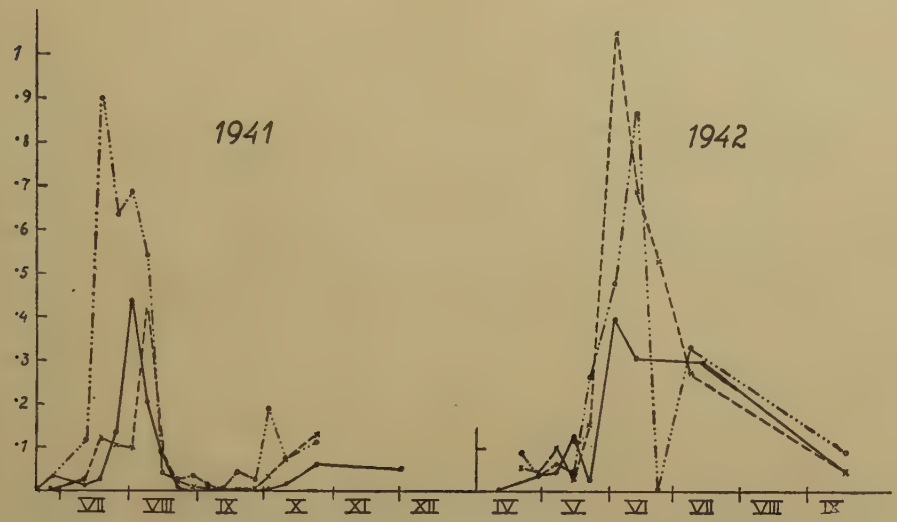

Fig. 24. Number of *Centropages hamatus* in 1941—42 in 1000's.
———— Paradisholmen, x- - - -x Marmorøya, o— . . . —o Bønes.

In the Nordåsvatn, *C. hamatus i*s rather scarce.

The numerical variation in 1941—42 is shown in fig. 24.

In 1941 numbers were less than 50 until the beginning of July, reached maximum in the outer fjord in the middle of the month, in the inner fjord at the beginning of August. Later the numbers decreased rather suddenly. In 1942, there was a maximum number at all stations in the first half of June.

Distribution of stages. The smaller nauplius stages pass through the meshes of the net. The variation in percentages of

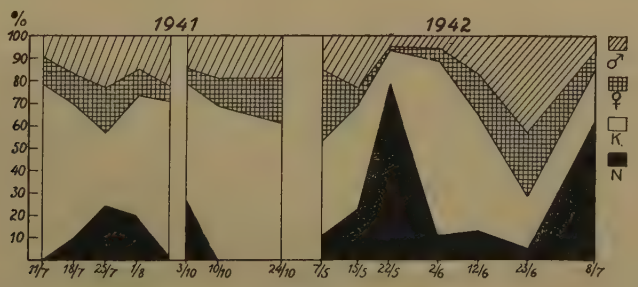

Fig. 25. Stock composition of *Centropages hamatus* in 1941—42.

the adults, copepodites, and nauplii in July—August and October 1941 and May—July 1942 is shown in fig. 25. — At other times the numbers were too small to give reliable figures.

The adults had maximum percentage July 25. 1941, May 7. and June 23. 1942. Minima occurred May 22. and July 28. 1942. The copepodites had maximum occurrence July 11, August 8. and October 10. 1941, May 15. and June 2. 1942, the nauplii had maxima July 27. and October 10. 1941, May 2. and July 8. 1942.

To judge from the maxima of the nauplii the main spawning would take place in the latter half of May, July and September.

In the spring and early summer of 1941 conditions in the Nordåsvatn were very unfavourable, and very little spawning took place.

Centropages hamatus was mainly caught in the upper 10—15 m. In 1942, a greater part of the stock at Marmorøya was taken in the 5—0 m haul.

Temora longicornis Müller.

In the Herdla- and Hjeltefjord *T. longicornis* is absent in December and January, scarce in February—April and October—November, common from May to September. (Runnstrøm 1932.)

The numerical variation of *T. longicornis* in the Nordåsvatn in 1941—42 is shown in fig. 26.

In 1941, *Temora* was scarce from May to the beginning of July, common from the middle of July to the beginning of September, and again scarce after the middle of September. Maximum number occurred in the beginning of August. In June 1942 there was a mass occurrence with far greater numbers than in 1941. Whereas in 1941 the largest stock was found in the outer fjord, with decreasing numbers inwards, this was not so marked in 1942.

Propagation. The relative average percentages of males, females, copepodites and nauplii during 1941—42 are shown in fig. 27. Only the later nauplius stages are caught. The earlier stages easily pass through the meshes of the net.

Major part of the stock of *Temora* consists of copepodites in various stages. The percentage curve for the nauplii shows maxima in May, July—August and September—October 1941, and May 1942, indicating at least 3 periods of more intense propagation a year. In 1941 the July brood seems to have been most successful, to judge after the increase in number at the beginning of August. In 1942 the May brood was more successful than in 1941, apparently on account on the more favourable hydrographic conditions.

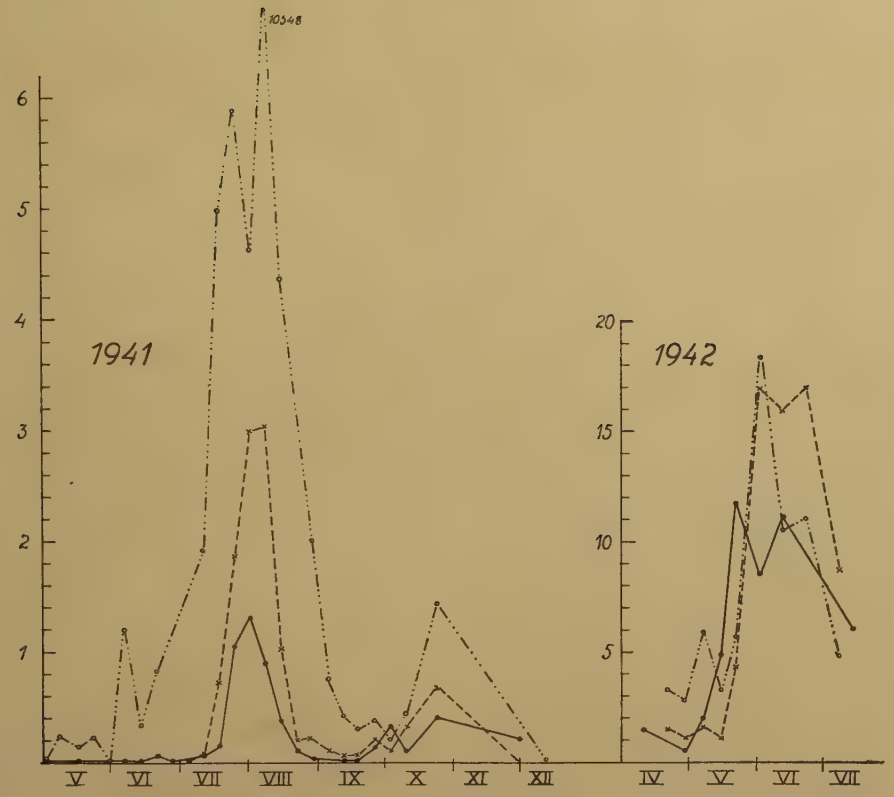

Fig. 26. Number of *Temora longicornis* in 1941—42 in 1000's.
———— Paradisholmen, x- - - -x Marmorøya, o— . . . —o Bønes.

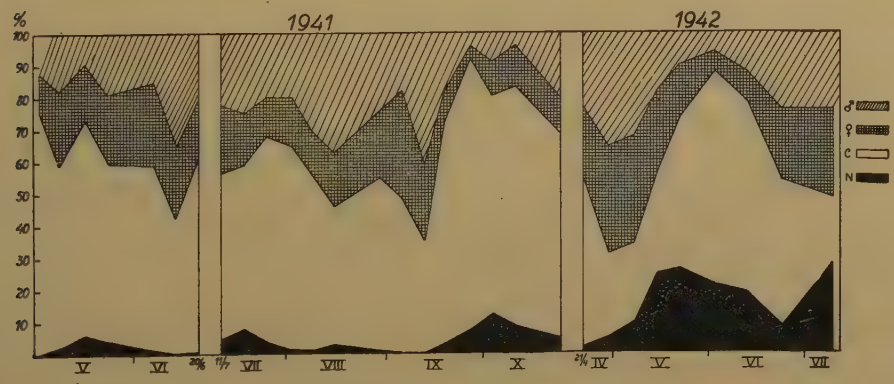

Fig. 27. Stock composition of *Temora longicornis* in 1941—42.

Vertical distribution. In the inner fjord *Temora* was mainly taken in the upper 15 m. In 1941 it probably frequented the layer between 12 and 15 m. In 1942 the bulk of the stock kept between 15 and 5 m, but minor quantities occurred in all depths.

In the outer fjord, the greatest number of *Temora* was also taken in the upper 15 m, except from August 15. to September 18. 1941, when a larger part was found in the 30—15 m haul. In 1942, the bulk of the stock frequented the 20—10 m layer. In the period June 2. to 23. there was an increasing quantity in the upper 10 m, in with maximum occurrence June 23.

Acartia clausi Giesbrecht.

Runnstrøm (1932) states that *A. clausi* near Bergen has a maximum occurrence in May—June and August—November. This agrees closely with the conditions in the Nordåsvatn.

The numerical variation of this species in the Nordåsvatn during 1941 is shown in fig. 28.

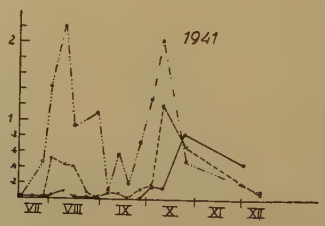

Fig. 28. Number of *Acartia clausi* in 1941 in 1000's.
———— Paradisholmen, x- - - -x Marmorøya, o— . . . —o Bønes.

A. clausi does not occur before the middle of June. There are maximum numbers in the first half of August and of October. The greatest numbers are found in the outer fjord, decreasing inwards. From April to July 1942 only single individuals were found. In September 216 specimens were caught at Bønes.

Propagation. The copepodites of stages I—III are easily confounded with those of *Acartia longiremis*. The nauplii of the two species cannot be separated at all. In table 6 are set forth the percentages of males, females and copepodites at Bønes during 1941.

Table 6. The percentage variation of males, females and copepodites of Acartia clausi at Bønes 1941.

Date	25/7	1/8	8/8	15/8	29/8	5/9	12/9	18/9	26/9	3/10	10/10	24/10	1/12
♂	**69.5**	45.5	25.0	**45.5**	21.8	**31.8**	17.8	13.3	13.9	21.6	14.6	**41.8**	34.0
♀	8.9	33.7	40.9	**45.5**	19.1	23.0	**51.6**	28.0	23.6	17.7	17.0	37.4	**66.0**
C	21.6	27.8	**34.1**	8.1	**59.1**	45.3	30.5	58.7	**62.5**	60.9	**68.4**	20.8	—

There is a certain periodicity in the percentage variation, corresponding to that of the total number. From July 25. to December 12. there seems to have been at least 3 succession of broods, July 25, September 5. to 12. and after October 24.

A. clausi in its vertical distribution is restricted to the upper 15 m or less. Only in the period August 2. to September 18. the major part of the stock at Bønes is taken in the 30—15 m haul.

Acartia longiremis Lilljeborg.

In the Herdla- and Hjeltefjord *A. longiremis* is numerous from May to August, but decreasing in number as early as September (Runnstrøm 1932).

The numerical variation of *A. longiremis* in the Nordåsvatn in 1941—42 is shown in fig. 29. This species is far more numerous than *A. clausi* and was present during all the time of investigation.

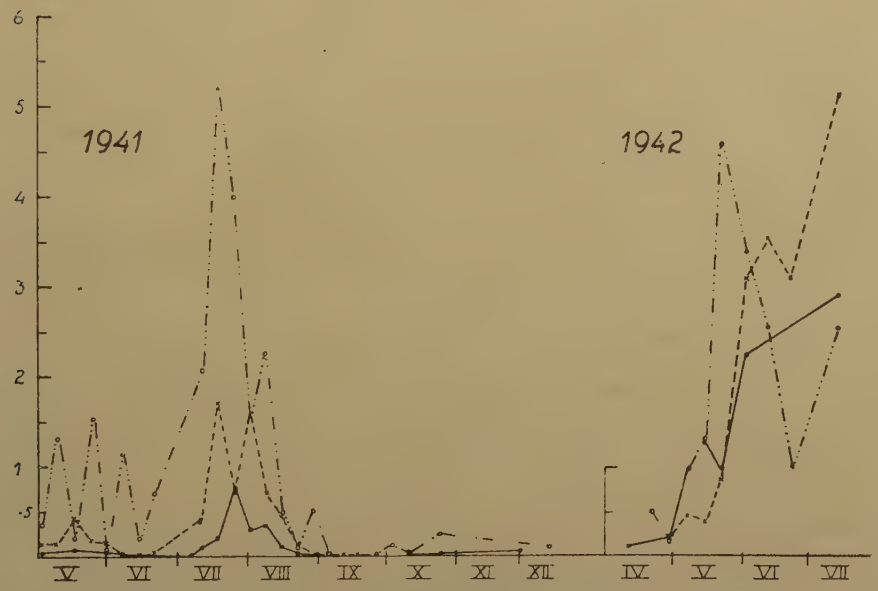

Fig. 29. Number of *Acartia longiremis* in 1941—42 in 1000's.
———— Paradisholmen, x- - - -x Marmorøya, o— . . . —o Bønes.

In 1941 there are maximum numbers in May and July, but otherwise great fluctuations. The numbers are always decreasing from the outer to the inner fjord. In 1942 the stocks are larger than in the previous year, but more evenly distributed. Numbers are steadily increasing from April to July, except in the outer fjord, where the

stock reaches maximum number in the middle of May, has a minimum at the end of June, and is again increasing in July.

Propagation. The nauplii and younger copepodite stages of *A. longiremis* cannot be discerned from those of *A. clausi*, but, when no adults and older copepodites of the latter species are present, the nauplii and younger copepodite stages with certainty can be referred to *A. longiremis*.

The average stock composition of *A. longiremis* in two periods of 1941 and one of 1942 is shown in fig. 30.

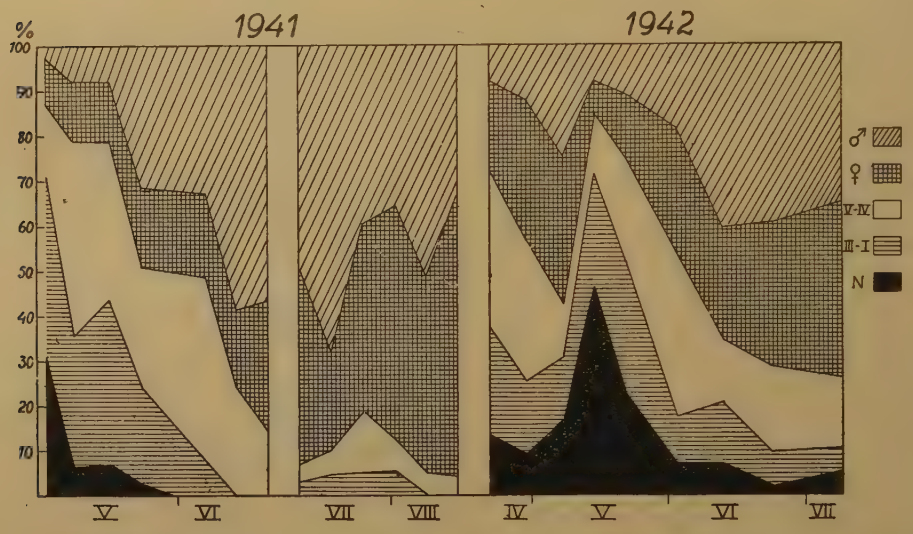

Fig. 30. Stock composition of *Acartia longiremis* in 1941—42.

In 1941 the main spawning probably took place at the end of April. In the outer fjord, the percentage of adults is steadily increasing throughout the summer, but at Marmorøya there are few adults until July 11. After that date, the stock composition is quite similar all over the Nordåsvatn. As the numbers are increasing greatly at all stations after July 11, but nevertheless mainly consists of adults, we must assume that the greater part of these have been introduced from the fjord outside the Nordåsvatn with a surface current.

In 1942 there has probably been a period of propagation before April 21. On April 10. the stock at Paradisholmen consisted mainly of nauplii (44 %) and copepodites of stages I—III (34 %). The main spawning takes place in May. The nauplii have maximum percentage in the middle of the month, the younger copepodites at the beginning of June. The adults have maximum occurrence at the end of June

end the beginning of July, and we may therefore assume, that the next spawning would take place in the middle of July. Probably there is an interval of 6 to 8 weeks between two generations of *A. longiremis*.

Males and females are alternatively more numerous.

In 1941, *A. longiremis* kept mainly between 10 and 15 m in the inner fjord, in the upper 15 m in the outer part. In 1942, there was a maximum occurrence at Marmorøya in the upper 5 m.

Other calanoids.

The following calanoids for a greater part do not belong to the copepod fauna of the Nordåsvatn, but occur more or less occasionally and in small numbers.

Calanus hyperboreus Krøyer was introduced in the early spring of 1942. Inmost, at Paradisholmen, 5 copepodites of stage IV were caught in the 20—0 m haul on April 10. and 2 specimens on May 27. At Marmorøya and Bønes *C. hyperboreus* was present from April 21. to July 8. in moderate numbers (4—67 specimens). Nearly all the specimens were taken in the deepest hauls. Copepodites of stage V were dominating all the time, except in the outer fjord on April 21, when copepodites of stage IV were in majority. Single specimens of stage III occurred April 21, 1 female on May 7.

Microcalanus pygmæus G. O. Sars was in 1941 found in the outer fjord in small numbers, maximum 60 specimens. In 1942 a few individuals also occurred in the inner fjord, but they soon disappeared, from Paradisholmen station after May 22, from Marmorøya after June 2. The latter locality in April—May had a stock varying from 106 to 250 specimens, on June 2. only 15 specimens. At Bønes the number was steadily decreasing from 325 sp. on April 21. to 40 sp. on July 8.

Microcalanus usually frequented the deeper water layers, but in 1941 single individuals were caught in the upper 15 m.

Pseudophaenna typica G. O. Sars. 1 female at Paradisholmen October 3. 1941 in the 12—0 m haul.

Scolecithricella minor Brady. 1 female at Marmorøya May 15. 1942 and one at Bønes April 21. 1942, both in the deepest hauls.

Stephos scotti G. O. Sars. 5 females and copepodites at Paradisholmen August 1. 1941 and 5 specimens at Bønes May 2. 1941.

Centropages typicus Krøyer. Single males at Paradisholmen October 3. 1941, Bønes August 22. 1941 and June 2. 1942.

Isias clavipes Boeck. In 1941 some individuals were caught in

the upper hauls in the outer fjord: September 12: 1 ♀. October 3: 25 ♂♂, 21 ♀♀, 121 copepodites. October 10: 14 ♂♂, 85 ♀♀, 93 cop. 25 nauplii(?). October 24: 21 ♂♂, 21 cop.

Metridia longa Lubbock. In 1941 single copepodites occurred at Bønes, one also at Marmorøya October 24. In 1942 this copepod was found at all stations, maximum number 142 specimens at Bønes on May 15. All stages were found, nauplii included. After May 22. numbers decreased greatly.

Nearly all the individuals were caught in the deepest hauls (in the outer fjord below 25 m). From May 22. to June 23. 1942 major part of the stock was taken in the 25—10 m haul.

Metridia lucens Boeck. In 1941 single specimens were caught in the outer fjord from August 29. to December 12. In 1942 it was also found at Marmorøya from April 29. to June 23, all the time in the deepest water layers.

Acartia discaudata Giesbrecht. Single individuals were taken at Paradisholmen August 1, October 24. 1941 and July 14. 1942, at Marmorøya July 25. and September 9. 1941, and at Bønes July 8. 1942. Both adults and copepodites occurred. Nordgaard (1899) records this species from the Puddefjord (Bergen harbour) G. O. Sars (1903) from Brattholmen near Bergen, Runnstrøm (1932) from a poole called Rosselandsvåg.

Oithona helgolandica Claus.

Off the west coast of Norway Ruud (1929) found maximum numbers in March—May, and in July or later. Runnstrøm (1932) mentions a maximum in the autumn.

The numerical variation of *O. helgolandica* in the Nordåsvatn in 1941—42 is shown in fig. 31.

O. helgolandica is always numerous and forms an important part of the animal plankton in the Nordåsvatn. In 1941 it is comparatively scarce till July 11. From that date there is an increase in number all over the fjord. In the inner part there was a maximum on August 1, but at Bønes the number did not culminate until the first half of September. In October there was a minimum, but in December numbers were again a little higher. In 1942 the stock of the inner fjord showed a rapid increase from April to May with maximum number in the latter half of May. A second maximum occurred in the middle of July or later. At Bønes there was a small maximum in June followed by a minimum. Later the number again increased and was very high in September.

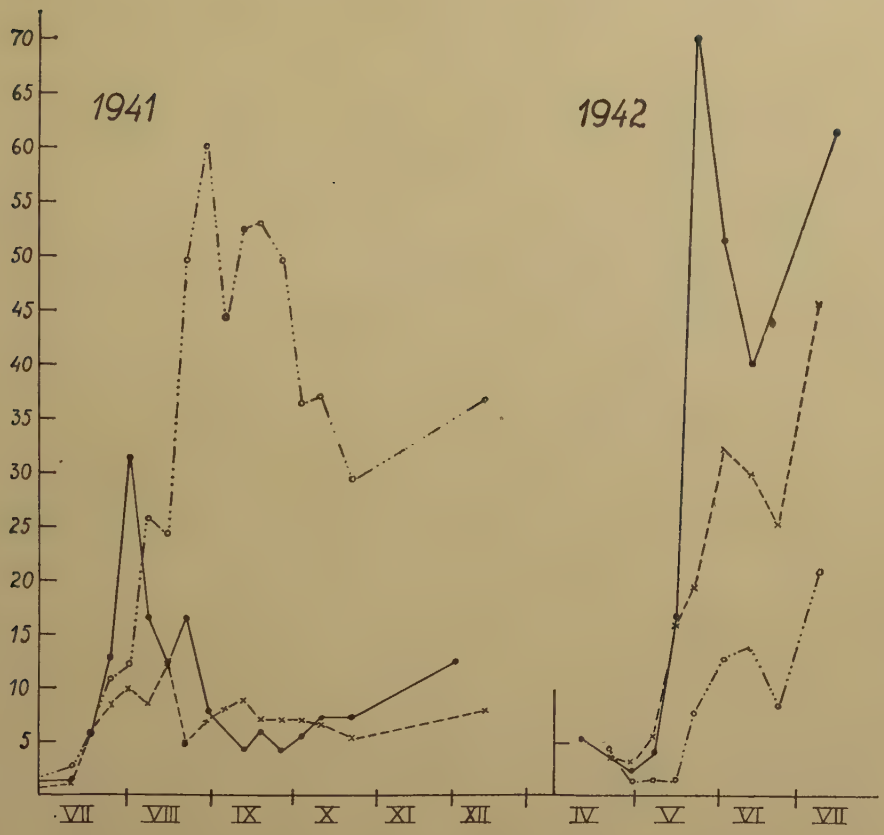

Fig. 31. Number of *Oithona helgolandica* in 1941—42 in 1000's.
———— Paradisholmen, x- - - -x Marmorøya, o— . . . —o Bønes.

The horizontal distribution was nearly identical both years, with greatest numbers in the inner fjord from April to August. Later in the year the largest stock occurred in the outer fjord. In the inner fjord the main period of propagation seems to be in August, in the outer part in September, with other spawning periods in March, May, and possibly November.

The number of copepodites always exceeded that of the adults, except from May 2. to July 25. 1941 and April 10. to May 15. 1942.

Some of the specimens of *Oithona helgolandica* differed a little in shape from the others. The cephalothorax was shorter and stouter than that of the other individuals. They ressembled a little of *Paroithona parvula*, but had a rostrum. The lenght of females was 0.63 mm. It may be a dwarf form of *O. helgolandica*, or a different species. I have not investigated the question any further.

Vertical distribution. In 1941 most part of the stock in the inner fjord probably frequented the water layer from 10 to 15 m, from October to December the upper 10 m. In the outer fjord the largest quantities were found in the 50—30 m haul, with decreasing quantities upwards. On October 24. and December 12. maximum numbers were caught in the 30—15 m haul.

In 1942 there was a more even distribution in all water layers, with maximum occurrence in the 15—5 and 5—0 m layer alternately. On September the greatest number was taken in the 25—12 m haul.

Oithona spinirostris Claus.

In the Nordåsvatn, *O. spinirostris* is always scarce. In 1941 single individuals were found in the outer fjord, maximum 25 specimens on August 8. In April 1942 this copepod occurred at all stations in small numbers, but disappeared from the inmost station as early as May 7.

The individuals were mainly females, and most often caught in the deepest hauls.

Oithona nana Giesbrecht.

Previously (1940) I have recorded this species from the Oslo Fjord. The numerical variation in the Nordåsvatn in 1941—42 is shown in fig. 32.

In 1941, *O. nana* is scarce from May to the middle of July. Later on the numbers increase, with maximum at Paradisholmen at the

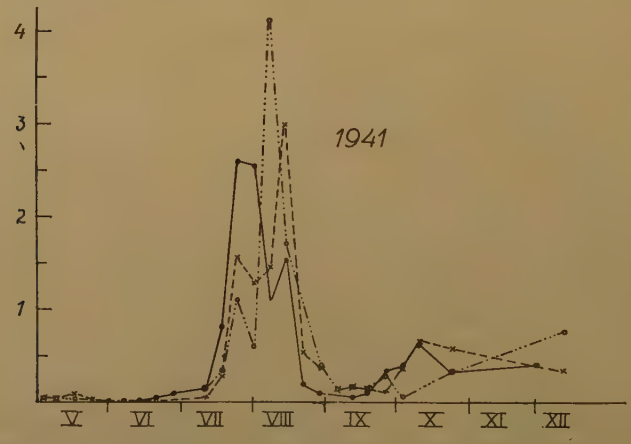

Fig. 32. Number of *Oithona nana* in 1941—42 in 1000's.
———— Paradisholmen, x- - - -x Marmorøya, o— . . . —o Bønes.

end of July, at the other localities in the first half of August. In September there is a common minimum. In the inner fjord there is a second maximum in the middle of October, in the outer part somewhat later.

In 1942, conditions from April to July were much alike those of 1941, but the numbers were a little higher, with a maximum of 560 specimens at Bønes at the end of May.

As a rule, *O. nana* is most numerous in the upper 10—15 m. In 1942, the greatest number was taken in the 5—0 m hauls at Marmorøya.

Oncæa borealis G. O. Sars.

In 1941, *Oncæa borealis* was found in the outer fjord in small numbers, maxima July 25. and September 5, 122 and 225 individuals respectively. In 1942 this species occurred in the whole fjord. Inmost the number varied between 0 and 20, at Marmorøya 5—56, at Bønes 15—180. Mainly females were caught, males and copepodites being comparatively scarce. At Bønes there was a greater percentage of copepodites and males July 25. 1941 and September 18. 1942, of copepodites also September 5. 1941.

O. borealis commonly kept in the water layers below 30 m.

Oncæa subtilis Giesbrecht.

This copepod has not previously been recorded from Norwegian waters. Cleve (1900, 2) found it at Plymouth, v. Breemen (1906) and Rose (1929) give the distribution to the Mediterranean, the Atlantic Ocean and the Skagerak. It has been impossible to ascertain who has recorded this copepod from the Skagerak. Farran (1908) has found it on the Irish Atlantic Slope, both near the surface and at greater depths.

V. Breemen (1906) gives the length of the female to 0.48—0.50 mm. Cleve (1900, 1) has a description of the male with length 0.4 mm.

Oncæa subtilis is very common in the Nordåsvatn. All stages were found, nauplii excluded. The length of the female is 0.54 mm, that of the male 0.37 mm (0.43 mm, setæ included).

The numerical variation in the Nordåsvatn in 1941—42 is shown in fig. 33.

In 1941 numbers are small all over the fjord until the middle of July, when there is a common increase. At Paradisholmen there are maximum numbers in August and October, minimum numbers

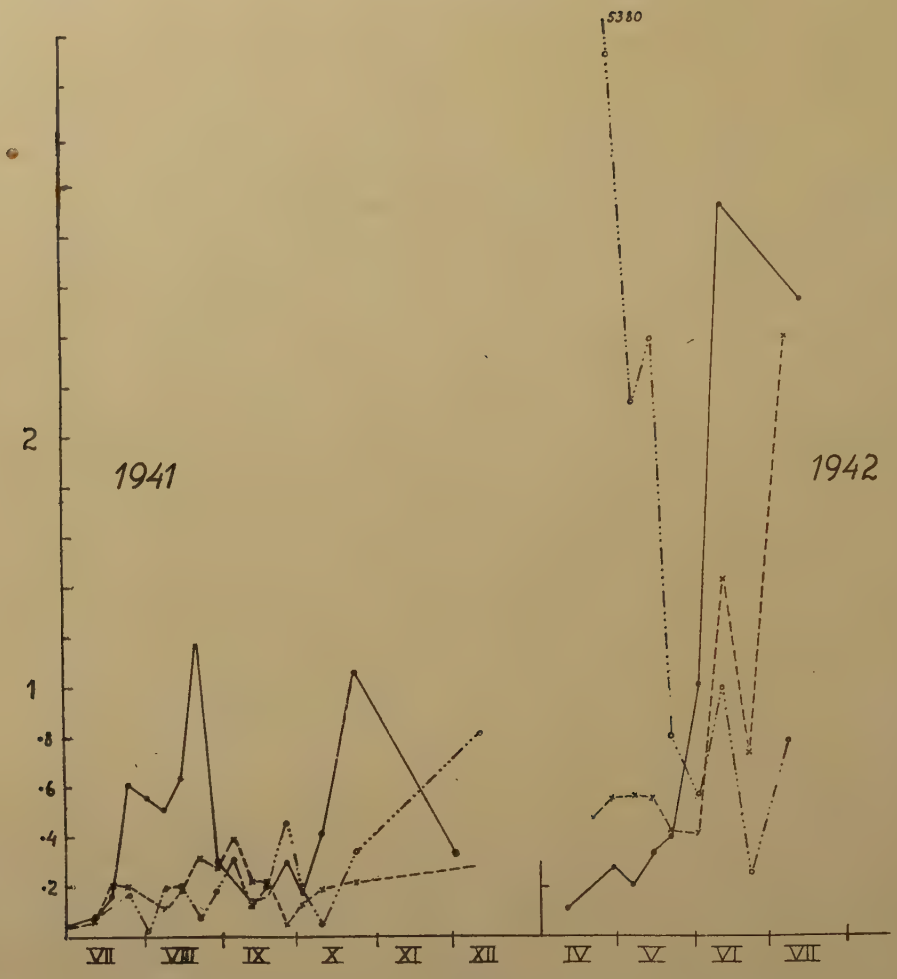

Fig. 33. Number of *Oncæa subtilis* in 1941—42 in 1000's.
———— Paradisholmen, x- - - -x Marmorøya, o— . . . —o Bønes.

in September and December. At Marmorøya and Bønes the stocks are much smaller and vary irregularly in size. There are two maxima in September. In the outer fjord the number is very high in December.

In 1942 the numbers are on an average much greater than the previous year. In the inner fjord the stocks are comparatively small from April to the beginning of June. Then the numbers begin to increase. Inmost there is a maximum in the middle of July or later, and a smaller maximum in September. At Marmorøya maximum occurs in the middle of June, followed by a minimum at the end of the month. Later the number is steadily increasing and is very high on September 18. In the outer fjord there is a maximum stock of

5400 sp. in April, then a decrease to a minimum in June. From the end of June the number is increasing, amounting to 9600 sp. in September.

Propagation.

A greater proportion of the smaller copepodites go through the meshes of the net. Probably some of the males also escape, as they are very slender. As a contrast to what was the case with *Oncæa borealis*, I seldom found *O. subtilis* in copulation.

In the inner fjord females with egg sacks were found from June 20. to December 12. 1941 and on June 2.—12, July 8, and September 18. 1942. In the outer fjord they were more scarce, but were observed from August 22. to 29. 1941, on July 8. and September 18. 1942. The males were a small proportion of the stocks, as a rule, less than 10 per cent.

The variations in percentage of the copepodites of *O. subtilis* in the inner fjord in July—December 1941 and at all stations in 1942 are shown in fig. 34.

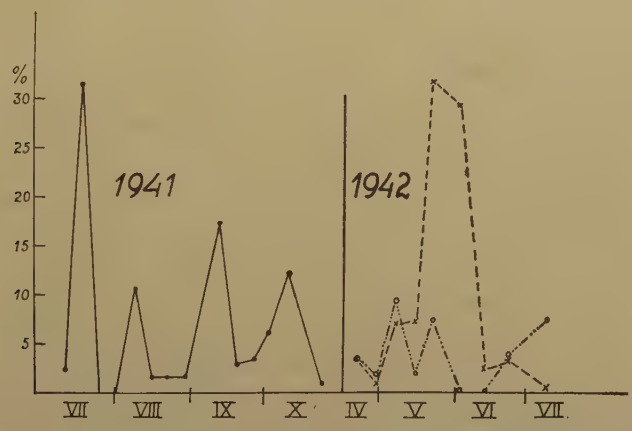

Fig. 34. Variation in the percentage of copepodites of *Oncæa subtilis* in 1941—42.
———— Paradisholmen, x- - - -x Marmorøya, o— . . . —o Bønes.

In 1941 the curve has 4 peaks between July and October. In April 1942 we have already passed the maximum. A second maximum follows at the beginning of June, and there probably is a third in August or September.

In the outer fjord the percentage of copepodites is much lower all the time, but maxima are indicated in May and July—September.

In comparing the percentage variation with the variation in num-

bers, it is evident that the propagation is going on a greater part of the year. Maximum of copepodites will occur some time after spawning. In 1941 there were periods of more intense propagation each month from July to October. The September spawning has probably been unsuccessful. In 1942 maximum of spawning takes place in March and July in the inner fjord, at the beginning of April and in July—August in the outer part.

Vertical distribution.

In 1941, the greater part of the stock of *O. subtilis* probably kept in the water layer from 10 to 15 m, since the bulk of the stock was caught in the 15—0 m hauls before August 22, and later, when the hauls were divided more according to the different water layers, in the 20—12 m hauls. In the outer fjord *O. subtilis* frequented the upper 15 m till August 15. After that date it went deeper. In the period August 22. to September 5. the greatest number was taken in the 30—15 m hauls, later in the 50—30 m hauls, with the exception of October 24, when most part of the stock was caught in the upper 15 m.

In 1942 the stock in the inner fjord was at first evenly distributed in the water layers below 15 m. From May 7. to 15. there was a somewhat greater concentration in the 15—5 m layer, and later nearly all the individuals were taken in the 5—0 m hauls. On September 18. the greatest number occurred in the 25—12 m layer. — In the outer fjord *O. subtilis* was at first caught in the 50—20 m hauls. After May 15. the greatest concentration was found in the upper 10 m. In September *O. subtilis* was evenly distributed in the water layers below 10 m.

The vertical distribution seems to have some connection with the season of the year. In summer we find *O. subtilis* in the upper 5—10 m. In August begins a migration towards deeper water, and from October to April *O. subtilis* keeps in the deepest parts of the Nordåsvatn, assumed that there is sufficient quantities of oxygen.

Other cyclopoids have been found singly, mostly copepodites, but they have not been determined.

Harpacticoids were regularly present, but scarce in number. Owing to the difficulties in determining them, they were only partly identified. The following species occurred: *Longipedia coronata* Claus, *L. scotti* G. O. Sars, *Ectinosoma sp.*, *Microsetella norvegica* Boeck, *Harpacticus uniremis* Krøyer, *Idya furcata* Baird, *Dactylopusia*

vulgaris G. O. Sars, *Amphiascus nasutus* Boeck, *A. longirostris* Claus, *A. giesbrechti* G. O. Sars, *Mesochra sp., Ameira tau* Giesbrecht, *Ameira sp., Laophonte sp.*

Of these species only *Microsetella norvegica* is really planctonic.

Nicholls (1935) has given a full description of the nauplii and copepodites of *Longipedia coronata, L. scotti* and *L. minor.* The nauplii of *L. coronata,* and nauplii and copepodites of *L. scotti* were found in the Nordåsvatn in moderate numbers in 1941—42.

The number of *L. coronata* nauplii was usually 20—30, with maxima July 25. 1941 (150 sp.) and October 10. 1941 (152 sp.).

The *L. scotti* nauplii varied much more in number. In 1941 there were 5 maxima from June to October, with intervals of 3—4 weeks. The June maximum was found only at Bønes, where the September maximum, in turn, was lacking. The maximum numbers varied between 60 and 400 specimens.

Copepodites of *L. scotti* were found regularly from June to December 1941. The numbers had irregular variations, with greater maxima at the end of June (60), August (550) and October (125).

All the harpacticoids were mostly found in the upper 10—15 m.

Other organisms.

Cladocera.

Evadne normanni Lovén is common in the Herdla- and Hjeltefjord from April to November, numerous from May to September (Runnstrøm 1932).

In the Nordåsvatn, (see fig. 35) *Evadne* occurred during all the time of investigation, but was very scarce in May—June 1941 and from the end of August to the beginning of October. In July—August and October there were distinct maxima. In April 1942 *Evadne* was scarce. Numbers increased in May, and maximum occurred in the first half of June. On September 18. numbers were low.

In 1941 there were nearly always decreasing numbers from Paradisholmen towards the outer fjord. Individuals with resting eggs were found from July 11. to August 8. and from September 18. to October 10, in 1942 from June 12. to July 8. Males occurred June 6.—13, October 3. 1941 and April 29. to May 7. 1942. On October 24. and December 12. 1941 the *Evadne* were very small, brownish, without embryos or resting eggs.

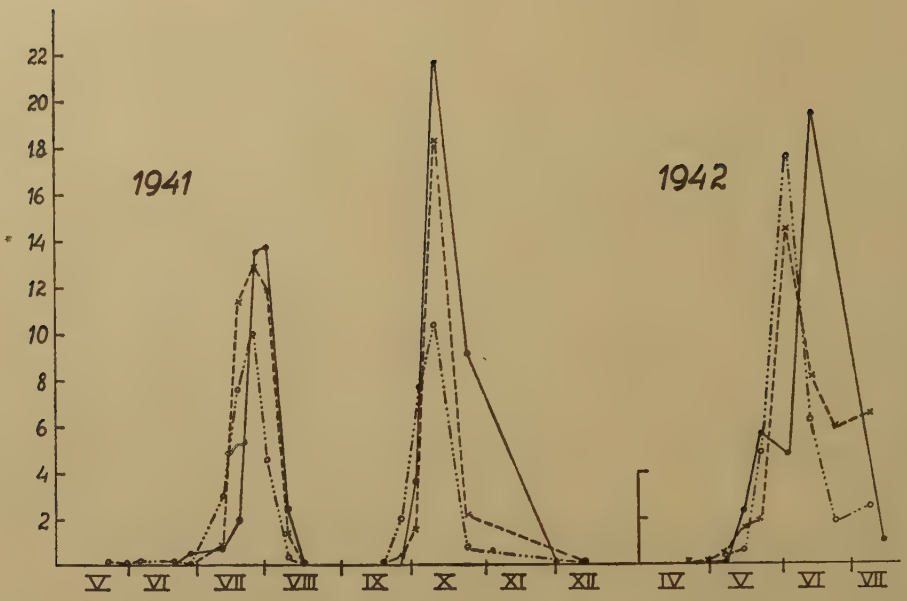

Fig. 35. Number of *Evadne nordmanni* in 1941—42 in 1000's.
———— Paradisholmen, x- - - -x Marmorøya, o—. . . —o Bønes.

Podon polyphemoides (Leuckart), *P. leuckarti* G. O. Sars, and *P. intermedius* Lilljeborg all occurred in the Nordåsvatn in 1941. The numerical variations of the three species are shown in fig. 36.

Podon polyphemoides was present from May to October, but numerous only from June to August. During these months there were two maxima at Paradisholmen, June 27. and July 25. At Marmorøya and Bønes maxima occurred in the first half of July. The greatest numbers were always found at Paradisholmen. In May, last half of September, and in October only single individuals were caught. In 1942 *P. polyphemoides* occurred in small numbers at Paradisholmen on June 12. and July 14, and at Marmorøya and Bønes on September 18.

Podon intermedius was in 1941 taken in two periods, in July—August and in October. It was always scarce, never exceeding 100 specimens. In 1942 it was lacking.

Podon leuckarti had in 1941 a medium-sized stock. It was present from June to August and in October. Inmost in the Nordåsvatn maximum numbers occurred on August 1, at the other stations in the first half of July. In 1942 *P. leuckarti* was more numerous and present during all the time of investigation. At Paradisholmen maximum numbers occurred May 15. and June 12, at Marmorøya and Bønes June 2.

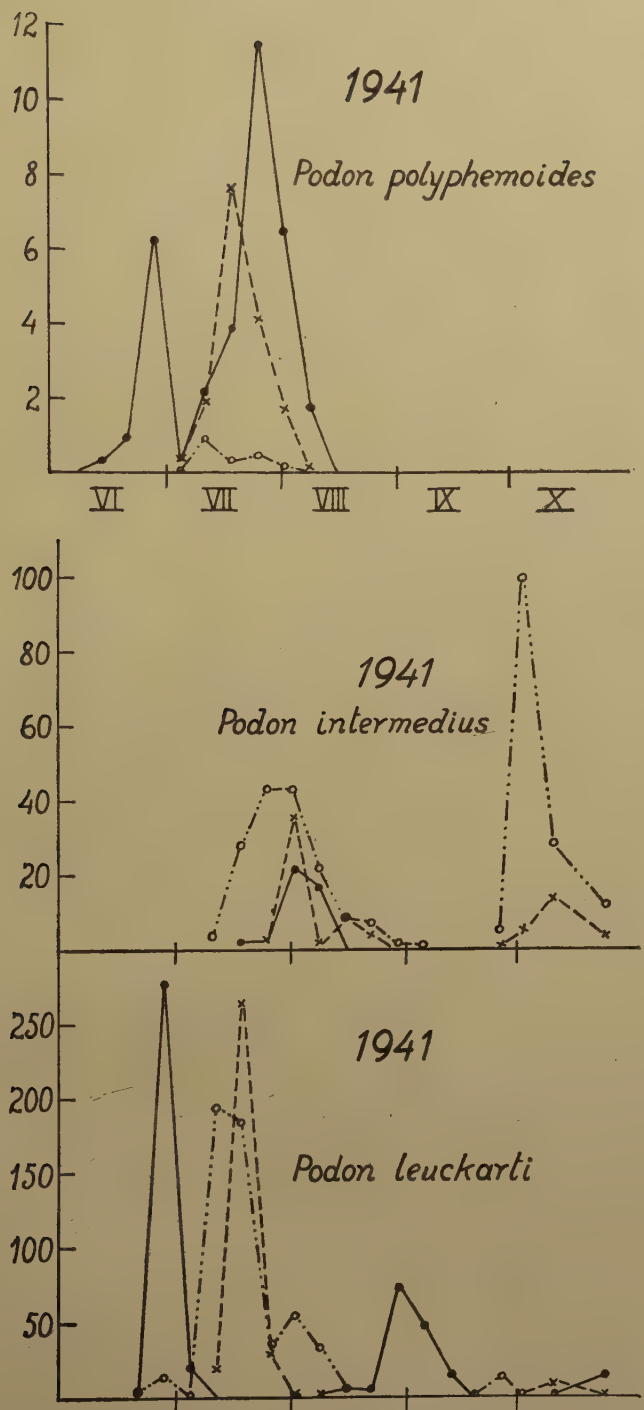

Fig. 36. Number of *Podon spp.* in 1941, *P. polyphemoides* in 1000's.
———— Paradisholmen, .x- - - -x Marmorøya, o— . . . —o Bønes.

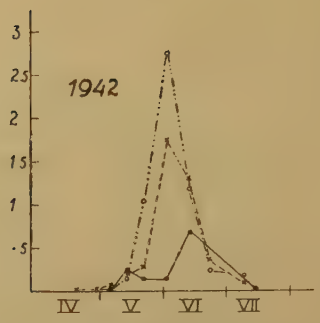

Fig. 37. Number of *Podon leuckarti* in 1942 in 1000's.
———— Paradisholmen, x- - - -x Marmorøya, o—. . . —o Bønes.

All the cladocera belong to the upper 15 m, and in 1942 the greatest concentration occurred in the upper 5 m.

The following species occurred singly: *Daphnia longispina cristata* O. F. M. was found at Paradisholmen June 13. to August 15. 1941 and September 18. 1942, at Marmorøya July 25. 1941, at Bønes July 18.—25. and August 15. 1941.

Diaphanosoma brachyurum Lievin occurred at Paradisholmen July 18. 1941 and at Bønes May 15. 1941.

Bosmina obtusirostris G. O. S. *(coregoni maritima ?)* was taken at Paradisholmen August 8.—15. 1941 and April 10. 1942, at Marmorøya August 22. to September 12. 1941 and June 12. 1942, at Bønes July 18. and August 8. 1941.

Decapoda.

Adult decapods were not caught in the plankton hauls, but various larvæ occurred. Larvæ of different prawns were found sparsely from April to October both years, maximum numbers in July 1941 and May 1942. *Pandalina brevirostris* (Rathke) was the most common species caught, but *Crangon crangon* (L.) *Hippolyte sp. (Leander sp.?)* and probably *Pandalus montagui* Leach also occur. *Athanas nitescens* (Montagu) was taken twice, at Bønes August 8. 1941, and at Marmorøya May 22. 1942.

Larvæ of pagurids, mainly of *Eupagurus bernhardus* (L.) occurred regularly at Bønes from June 6. to September 5. 1941, most numerous from July 4. to August 8, maximum 43 ind. on July 18. Single individuals were taken at Marmorøya July 18. to September 12. and October 24. 1941. In 1942 pagurid larvæ were caught at Paradis-

holmen on May 15. (2. ind.), at Marmorøya from May 5. to July 8, and at Bønes from April 21. to September 18.

Larvæ of *Galathea sp. (rugosa)* were present in the outer fjord from July 18. to August 28. 1941, maximum 22 specimens. Single specimens appeared from April 21. to May 7. 1942. 2 individuals were caught at Paradisholmen September 26. 1941, single ind. at Marmorøya May 7.—15. 1942.

Munida sp. 1 larva at Marmorøya, and 1 at Bønes May 15. 1942.

Brachyura larvæ were regularly present. *Carcinus moenas* (L.) larvæ occurred from June 13. to September 26. 1941, and from June 12. to September 18. 1942. Maximum numbers: Paradisholmen July 18. 1941, 125 specimens. Marmorøya June 12. to July 8. 1942, 32 ind. Bønes July 18. 1941, 65 ind. July 8. 1942, 21 ind.

Portunus sp. (puber). Marmorøya August 8. 1941, 2 larvæ, September 18. 1942, 1 larva. Bønes October 24. 1941, 1 larva.

Hyas araneus (L.) larvæ were taken in moderate numbers from April 21. to July 8. 1942. Maximum numbers: Paradisholmen May 7.—15. 10 ind. Marmorøya May 7.—15. 14 ind. Bønes May 15. 36 ind., June 12. 29 ind.

Porcellana platycheles (Pennant). In 1941 single larvæ occurred at Paradisholmen September 12.—26. and October 24, at Marmorøya September 18, and at Bønes August 15. and September 18.

According to Balss (1926) adults of this species occur at the Shetland Islands, but on the eastern side of the North Sea do not pass the 54th degree.

Euphauciacea.

Adults of *Thysaonessa inermis* Krøyer were found singly at Bønes from July 18. to September 12. 1941, and at Marmorøya June 12. 1942.

Larvæ of euphauciids occurred in small numbers nearly all the year. In 1941 they were mainly taken in the outer fjord, in April 1942 at all stations. N a u p l i i were present June 6. 1941 and April 10.—21. 1942, m e t a n a u p l i i April 21. 1942, c a l y p t o p i s larvæ June 6.—13. 1941 and April 21. to June 12. 1942, f u r c i l i a June 6. to August 1. 1941 and April 29. to June 12. 1942, c y r t o p i a May 2. to August 8. 1941 and May 21. to July 8. 1942.

One calyptopis larva of *Meganyctiphanes norvegica* (M. Sars) was taken at Bønes May 7. 1942.

A m p h i - and I s o p o d a (not *Themisto* or *Hyperia)* occurred singly, but were not determined.

Chætognatha.

Sagitta setosa Müller and *S. elegans* Verril are both present in the Nordåsvatn in 1941—42, but, as far as I can see, *S. setosa* is scarce and can be left out of consideration.

In 1941, *S. elegans* occurred regularly in the outer fjord only. Average numbers, eggs included, for the months May—October were 1, 18, 62, 615, 1044, 746, for December 156 specimens. In reality there were maxima on September 5, 1116 specimens, and October 24, 1140 sp. with a minimum in the intervening period. From August 1. to October 24. the stock mainly consisted of eggs and newly-hatched specimens. Percentage curves of these two groups in the outer fjord in 1941—42 are shown in fig. 38. In 1941 the curve of the eggs has maxima in the middle of August and the beginning of October, that of the newly-hatched larvæ at the beginning of September and the end of October.

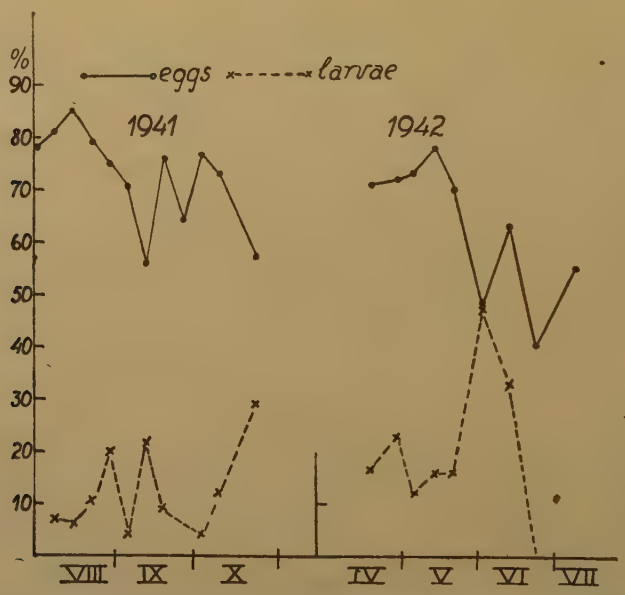

Fig. 38. Percentage distribution of eggs and newly-hatched larvæ of *Sagitta elegans* at Bønes in 1941—42.

In 1942 *S. elegans* was present at all stations. The monthly average values were as follows:

	April	May	June	July	Sept.
Paradisholmen	40	171	188	76	21
Marmorøya	97	546	264	213	170
Bønes	224	810	927	641	238

The numbers are always decreasing from the outer to the inner fjord. At Paradisholmen there are maxima May 7. and June 2, 221 and 191 specimens respectively, at Marmorøya May 22. (697 sp.), at Bønes May 22. (1256 sp.). The curve for the percentage of eggs (fig. 38) has peaks in the middle of May, middle of June and after July 14. In September the percentage of eggs is also fairly high. The percentage curve for the newly hatched larvæ have to maxima, a smaller one at the end of April, and a higher one in the middle of June.

Russell (1932—33) has made thorough investigations concerning spawning and length variations of *Sagitta elegans* and *S. setosa.* According to this investigations, the eggs of *S. elegans* have a diameter of 0.334—0.394 mm, those of *S. setosa* 0.13—0.19 mm (in situ).

In the Nordåsvatn, the *Sagitta*-eggs measured 0.297—0.307 mm, and thus undoubtedly belonged to *S. elegans.* The length of the newly-hatched larvæ was 1.3—1.6 mm. September 18. 1941 the adults of *S. elegans* measured 16 mm, from April 21. to May 7. 1942 15—22 mm. Runnstrøm (1932) for the adults in the Herdla- and Hjeltefjord indicates a length of 20—24 mm in May—November.

Adult individuals, probably belonging to *S. setosa,* measured August 8.—15. 1941 9.3—10.0 mm, April 10. 1942 13 mm.

Vertical distribution. In 1941, nearly the entire stock of *S. elegans* was taken below 15 m. The adults frequented the 30—50 m layer, whereas the eggs and smaller individuals were caught in the 15—50 m layer. In 1942, most part of the stock kept below 15 m at Paradisholmen. At Marmorøya adults and eggs from April 21. to June 23. were taken in the 80—40 m haul, some also in the 40—15 m haul. The newly-hatched larvæ and smaller individuals kept higher up, mostly in the 15—5 m layer. On July 8. and September 18. the bulk of the stock was taken in the 25—12 m haul. At Bønes adults and eggs were chiefly found below 25 m, newly-hatched larvæ and smaller individuals above 15 m.

Copelata.

Runnstrøm (1932) records 9 species of copelata from the Herdla- and Hjeltefjord. In the Nordåsvatn, I have found only 2 species, namely, *Oikopleura dioica* Fol, and *Fritillaria borealis* Lohmann.

Oikopleura dioica was comparatively numerous in the Nordåsvatn in 1941 (fig. 39). With the exception of 5 individuals caught June 6. at Bønes, it did not appear till July 11. In the inner fjord there were maximum numbers July 25. and October 3.—10, in the

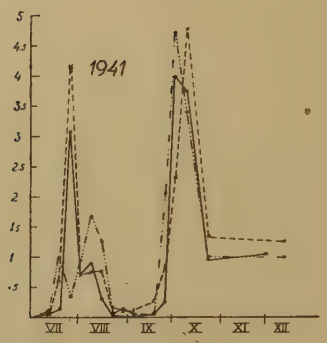

Fig. 39. Number of *Oikopleura dioica* in 1941 in 1000's.
———— Paradisholmen, x- - - -x Marmorøya, o— . . . —o Bønes.

outer fjord July 11, August 8. and October 10. In September numbers were small at all stations.

In 1942, *O. dioica* was scarce, with a maximum in the inner fjord at the beginning of May.

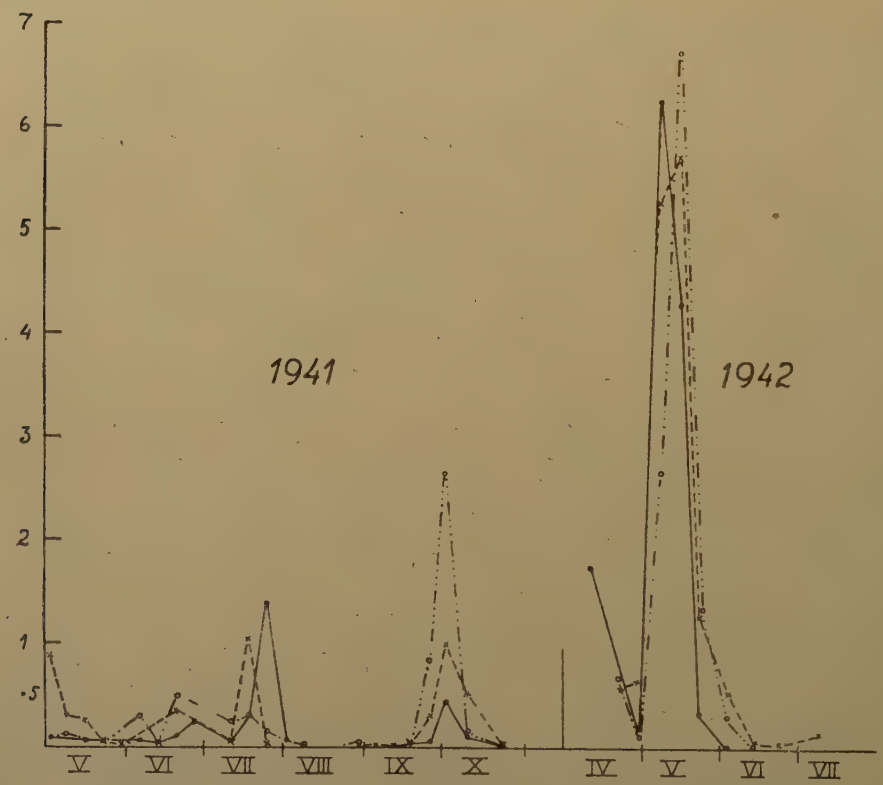

Fig. 40. Number of *Fritillaria borealis* in 1941—42 in 1000's.
———— Paradisholmen, x- - - -x Marmorøya, o— . . . —o Bønes.

Fritilliaria borealis was not as numerous as *Oikopleura*. The numerical variation during 1941—42 is shown in fig. 40. In 1941 there probably was a maximum in the inner fjord before May 2. During May and June the number varied irregularly. In the latter half of July there was another maximum. In August *Fritillaria* was partly lacking, in September it was scarce. At the beginning of October there occurred a second higher maximum. In the outer fjord there was a less pronounced maximum in June, while the main maximum of the year occurred in October.

In 1942 a maximum was indicated on April 10. or earlier. In May numbers were high at all stations, but declined quickly in June In September numbers were low.

Both species of copelata frequent the upper 12—15 m, at Marmorøya the upper 5 m from April 29. to June 2. 1942. In the period June 12.—23. 1942 *Fritillaria* sought greater depths, at Marmorøya the 40—15 m layer, in the outer fjord the 25—10 m. Small numbers of copelata are always found in the deeper water layers. *Oikopleura* is sometimes more evenly distributed in the different water layers than *Fritillaria*.

Polychæta.

Tomopteris sp. (larvæ). Single specimens at Marmorøya September 12. 1941, Bønes September 26. and October 3. 1941, July 8. 1942.

Autolytus sp. with eggs was taken singly at Marmorøya July 25. 1941, Bønes June 20, July 25, October 10. 1941 and June 23. 1942.

Larvæ of bottom evertebrata.

Larvæ of bottom polychæta were scarce from May to the middle of July 1941. In the inner fjord numbers increased later with maximum numbers August 1.—15. at Paradisholmen and August 29. at Marmorøya. (5000 ind.) Smaller maxima occurred in October. In the outer fjord, numbers were always low, maximum 1000 ind. in October. In 1942 there were on the whole higher numbers, 1200—1800 from April to May 15. In June there was a minimum, but after June 12. the numbers increased steadily and were very high in September.

Nauplii and cypris-larvæ, probably of *Verruca strømi* O. F. Müller and *Balanus improvisus* Darwin, were taken May 16. to 30. and July 4. to August 15. 1941 at Paradisholmen, May 2. to July 18. and October 3. 1941 at Marmorøya, May 2. to December 12. at Bønes. Numbers

(maximum 40—60) were always decreasing from the outer fjord and inwards. Not uncommon was a nauplius similar to that of *Peltogaster purpureus* (Fr. Müller), the scutellum being of a more oval shape.

In the spring of 1942 nauplii and cypris-larvæ of *Balanus balanoides* (L.) occurred in fairly high numbers (Paradisholmen April 10. 561 sp. Marmorøya April 21. 694 sp. Bønes April 21. 542 sp.) decreasing to May 15.—22. From June 2. to 12. there was a second maximum probably of *Verruca larvæ* (290 to 551 sp.).

The *Cyphonautes*, larvæ of *Membranipora sp.*, occurred sparsely from May to September both years, but were numerous in October. (Paradisholmen October 24. 760 sp. Marmorøya October 10. 1050 sp. Bønes October 24. 458 sp.).

Larvæ of mussels. In the Nordåsvatn there is a large stock of the sea mussel, *Mytilus edulis* L. The majority of the mussel larvæ belongs to this species.

In 1941 the mussel larvæ were numerous from May to the end of June, with a maximum in the former half of June (Paradisholmen 7018 sp. Marmorøya 1800 sp. Bønes 1600 sp.). In July—September numbers were scarce. In the middle of October there was a second maximum. In December the numbers were also fairly high. Similar conditions prevailed during 1942.

Larvæ of gasteropods. Egg capsulæ and larvæ of *Littorina littorea* L. occurred regularly with maxima in July—August (Numbers 1600—3000) and October. Larvæ of *Trivia arctica* L. and possibly *Patella vulgata* L. were also found, mainly at Bønes from August 8. to December 12. 1941.

Larvæ of echinoderms. Auricularia and bipinniaria larvæ were taken in small numbers from May 2. to July 18. 1941. From July 25. to October 24. echino- and ophioplutei were present, with maxima in September. In 1942 young bipinnaria larvæ were very numerous all the time, at Paradisholmen maximum number 4657 on June 12, Marmorøya: 2121, May 7. to July 8, Bønes: 500, June 2. Echino- and ophioplutei also occurred.

Eggs and larvæ of ascidians were most numerous in the inner fjord from July 18. to August 8. 1941 (170—180 specimens per haul). At Bønes eggs and larvæ occurred in greater numbers and in two periods: July 18. to August 8. (Maximum 157 sp.) and October 3.—24. (Maximum 530 sp.). In 1942 eggs and larvæ of ascidians were scarce or lacking in the inner fjord. At Bønes there was a maximum number on May 22, especially of eggs. Larvæ of the type *Ascidia callosa* (Stp.) occurred most commonly. (See Huus, 1933).

Coelenterata.

Sarsia tubulosa (M. Sars) did not appear in 1941. In 1942 it was quite common at Marmorøya and Bønes from April 21. to July 8, most numerous in the outer fjord (Maximum 78 specimens).

Bougainvillia superciliaris L. Agazzis. In 1942 single specimens occurred from May 2. to June 23, mostly in the outer fjord.

Bougainvillia ramosa probably is also present. Kramp and Damas (1925) describe (loc. cit. pag. 54) a new variety, *var. minima,* from the Nordåsvatn.

Rathkea octopunctata (M. Sars) was found in moderate numbers October 24. and December 12. 1941. In 1942 it was very common from April to the end of June. Numbers increased steadily till June 2, when 375 specimens were caught at Marmorøya, about 100 at Bønes. Later on the numbers decreased, and in July they were low.

Rathkea octopunctata was most common in the 15—5 m layer in the inner fjord, in the outer fjord between 25 and 10 m.

Neoturris pileata (Forskål) *(Leuckartiara octona ?)* 1 specimen with 22 tentacles at Paradisholmen September 12. 1941.

Melicertum octocostatum (M. Sars). This species occurred regularly at all stations from June 13. to October 24. 1941, greatest numbers (51—85) in the outer fjord in August—September. In 1942 very small individuals were found from May 15. to September 18. From July 8. larger individuals began to appear. Kramp and Damas (1925) have found this medusa in the Nordåsvatn and state that it prefers brackish water.

Tiaropsis multicirrata (M. Sars) was found singly in May—June 1942. 1 specimen measured 16 mm in diameter. Another specimen had 232 tentacles and a diameter of 12 mm.

Obelia nigra Browne was taken on April 21. and June 23. 1942, mostly in the outer fjord.

Phialidium hemisphæricum (L.) occurred from August 18. to October 24. and on December 12. at Marmorøya and Bønes.

Eutonina indicans (Romane) 1 specimen at Bønes July 8. 1942, diameter 40 mm.

Aequorea forskålea Peron et Lesueur. 1 unripe specimen with 55 radical canals at Bønes August 8. 1941.

Aglantha digitale (O. F. Müller) was taken at Bønes July 18. and August 8. 1941. In 1942 it occurred in the outer fjord from April 21, at Marmorøya from April 29, and from May 7. to June 12. at all stations. *Aglantha* was most common in the deeper hauls, but was on a few occasions taken in the upper 5 m.

Aurelia aurita. Some few specimens were present from May 8. to September 12. 1941 and in April 1942. Ephyra larvæ were found in the outer fjord December 12. 1941 and April 29. 1942.

Cyanea capillata L. One small specimen at Marmorøya June 2. 1941, ephyra larvæ at Paradisholmen April 10. 1942.

Dimophyes arctica (Chun.) One colony at Bønes July 25. 1941.

Pleurobrachia pileus O. Müller. Young individuals and fullgrown specimens occurred in moderate numbers from May 2. to August 8. 1941. On June 20., August 22. and September 18.—26. there were mass occurrences of eggs and small individuals. In 1942, *Pleurobrachia* was scarce. A few specimens were found on June 12.

Beroe cucumis Fabricius. In 1941 a few individuals were taken in the outer fjord from July 25. to December 12, mostly below 30 m. In 1942 some *Beroe* were also found at Marmorøya, mainly below 40 m.

Arachnactis bournei Fowl, the larva of *Cerianthus lloydi* Gosse was caught once in 1941, 5 specimens at Bønes June 6. In 1942, 1—10 specimens occurred regularly from April 21. to June 2. The individuals caught in April were small. On June 2. were found specimens with 9 tentacles, lenght of body 1.3 mm, body + tentacles 2.2 mm.

Turbellaria.

Alaurina composita Metschnikow, or an allied species. A few specimens were found at Paradisholmen December 1. 1941, May 22. and June 2. 1942, at Marmorøya December 12. 1941 and June 2. 1942, at Bønes July 8. 1942.

Larvæ of leptoplanids, *Notoplana almata* or allied species, occurred at Bønes from May 15. to June 13. 1941 and April 21. to July 8. 1942, maximum 12 specimens. At Marmorøya they were present from April 21. to June 2. 1942, at Paradisholmen from May 15. to 2. 1942.

Other larval turbellaria were caught singly.

Fish eggs and larvæ.

In 1941 fish eggs, chiefly of sprat *(Clupea sprattus)* were taken inn moderate numbers (3—40) from May 2. to August 1. Eggs of *Pleuronectes flesus* and *P. limanda* also occurred.

Sprat larvæ were found from June 20. to August 15. In the same period there also occurred larvæ of *Gadus merlangus, Pleuronectes flesus,* and *Gobius niger.*

In 1942 eggs and larvæ of the same species, with addition of

some cod eggs, were found during all the time of investigation, but the numbers were greater than the previous year. At Paradisholmen maximum May 7. 115 eggs, May 15. 28 larvæ. At Marmorøya more than 100 eggs (maximum 212) in the period April 21. to June 23. A larva of *Raniceps raninus*, length 2.6 mm was caught at Paradisholmen September 12. 1941, and a specimen, probably of the same species, at the same locality on August 1. 1941.

Summary.

1. In the Nordåsvatn, a land-locked water near Bergen, weekly observations were carried out from May to November 1941 and from April to July 1942 for the main purpose of studying the production of zooplankton. Investigations were made at 3 main stations, 2 in the inner part, 1 in the outer part of the Nordåsvatn, comprising hydrographic-chemical observations, water samples for phytoplankton and samples of zooplankton, collected in vertical hauls with a closing net. In 1941 the hauls in the inner fjord were mostly made in 2 steps from the border of the H_2S layer to the surface, in the outer fjord in 3 steps from bottom to surface. In 1942 the hauls were made in 3—4 steps from bottom to surface in all parts of the fjord.
2. The plankton material was immediately fixed in formalin. Definite fractions of the samples were taken out by Lea's Plankton Divider and counted.
3. A. The topography of the Nordåsvatn and its hydropgraphic conditions 1941—42 are dealt with. Investigations by Gaarder (1916) have shown that the Nordåsvatn is a landlocked water and can be divided into an outer and an inner fjord, separated by a threshold in 12 m depth at Bønes. In the inner fjord the water layer below 15 m may be stagnant for years, and, as a rule, contains H_2S. The renewal of the bottom water takes place irregularly, chiefly in winter and early spring, in years with little precipitation. In the outer fjord the water layer below 20 m may also contain H_2S, but here the bottom water is renewed regularly once a year.

   B. The surface layer is well aerated, with great changes in temperature and salinity during the year. The upper 1 m generally contains brackish water. Below 1 m the salinity commonly is higher than 27 $^0/_{00}$.

   C. The hydrographic-chemical investigations in 1941—1942 include observations on temperature, salinity, and of oxygen content.

D. The picture given by Gaarder (1916) of the hydrographic conditions, has not been essentially altered. A renewal of the bottom water of the outer fjord took place in the early spring of 1941 and could to a minor degree be perceived in the inner fjord. In the early spring of 1942 a very extensive renewal of the bottom water took place in all parts of the Nordåsvatn.

E. The oxygen in the deeper water layers of the outer fjord was consumed more rapidly in the summer of 1942 than that of 1941.

4. The population of zooplankton is at first treated as a whole. The number of organisms was low in May—June 1941, increased in July, and had maxima in July—August and in October in the inner fjord, at the end of August in the outer fjord, numbers there being twice as high as in the inner part. In 1942 numbers were low in April, increased in May, and had maxima in May, June, July, in the outer fjord probably in September.
5. The distribution of plankton organisms in relation to the hydrographic conditions is discussed.
6. The copepods form the greater part of the zooplankton, with the exception of June—August and October 1941, when the cladocera and benthonic evertebrate larvæ were very numerous in the inner fjord. In 1941 the percentage of copepods was higher in the outer fjord than in the inner part. In 1942 the case was the other way.
7. 16 species of Calanoida, 5 of Cyclopoida, and 14 of Harpacticoida have been found. The bulk of the copepod stock is composed of 5 calanoids and 2 cyclopoids, namely, *Calanus finmarchicus* (mean percentage 1941: 0.4, 1942: 8.4 %), *Pseudocalanus minutus* (13.3—7.6 %), *Paracalanus parvus* (May—September 1941 3.1 %, May—December 1941: 11.3 %, May—September 1942: 1.8 %), *Temora longicornis* (4.5—14.2 %), *Acartia spp.* (6.7—4.5 %), *Oithona spp.* (60.1—56.2 %), *Oncæa spp.* (1.8—6.1 %).
8. The copepod fauna of the Nordåsvatn is very poor as compared with that of the fjords outside.
9. *Calanus finmarchicus* was scarce in 1941, with maxima in August and October. In April 1942 it was numerous, numbers decreasing steadily to September. In 1941 some spawning occurred between July and October, mainly in August—September. A new stock introduced from the fjord outside the Nordåsvatn in April 1942 mainly consisted of nauplii and early copepodite stages. A new spawning took place in the outer fjord in September.

In 1941 the bulk of the *Calanus* in the inner fjord frequented the water layer between 12 and 15 m, in the outer fjord the upper 30 m, copepodites of stage V kept below 30 m. In 1942 the vertical distribution varied a little, but stage V, as a rule, frequented the deeper water layers.

10. *Paracalanus parvus* had always its greatest stock at Paradisholmen. In 1941 there were maximum numbers in August and October. In 1942 numbers were comparatively high in April, decreased to July and were again higher in September. Propagation takes place most part of the year. Maximum occurrence in the surface and intermediate water layers, some also in deeper waters.
11. *Pseudocalanus minutus.* Maximum numbers in the inner fjord: August and October 1941, May and August 1942. In the outer fjord: September 1941, June and September 1942.

    Propagation takes place most part of the year, maximum spawning in April, June—July and September—October.

    Vertical distribution as that of *Paracalanus*, on an average however, a higher percentage in the deeper water layers.
12. *Centropages hamatus* was always scarce. In 1941 maximum stock in July—August, in 1942 in June. Maximum spawning in May, July and September.
13. *Temora longicornis* was moderately numerous in July—September 1941, maximum number in August. In 1942 it was more abundant, with maximum in June. Maximum of spawning in May, July—August and September—October 1941, and May 1942. With some exceptions, most frequent between 15 and 5 m in the inner fjord, 20 and 10 m in the outer part.
14. *Acartia clausi.* Maximum numbers in August and October 1941, very scarce April—July 1942. Vertical distribution as for *Temora.*
15. *Acartia longiremis.* More common than the previous species. Maximum numbers in May and July both years, the May maximum lacking in the inner fjord in 1942. More restricted to the surface layers than *Temora.* In 1942 maximum occurrence in the upper 5 m in the inner fjord.
16. *Oithona helgolandica* is the most common copepod of the Nordåsvatn. The inner fjord had maximum numbers in July—August 1941 and May and July 1942, the outer fjord maxima in September 1941, June and probably September 1942. Maximum of propagation in August. Vertical distribution in 1941 mainly in the intermediate and deeper water layers, in 1942 in all depths, but maximum occurrence in the upper 15 m.

17. *Oithona spinirostris.* Scarce, in the deeper water layers, in 1941 confined to the outer fjord.

18. *Oithona nana.* Moderately numerous, maximum numbers in July—August and October both years. Keeps in the upper 10—15 m, in the inner fjord in the upper 5 m.

19. *Oncæa borealis.* Scarce, in 1941 only caught in the outer fjord, below 30 m.

20. *Oncæa subtilis.* New to the Norwegian fauna. In 1941 maximum numbers in the inner fjord in August and October, in the outer fjord a small stock and irregular variation in numbers. In 1942 the stocks were larger in all parts of the Nordåsvatn, with maxima in April, June—July, and September or later. Propagation the greater part of the year, in 1941 most intensively from July to October, in 1942 maximum of propagation in March and July in the inner fjord, in April and July—August in the outer part.

    Vertical distribution: In summer in the upper 5—10 m, in August—September a more even distribution in all water layers, from October to April in deeper water.

21. Common to all copepods: Spawning and maximum of numbers as a rule occur earlier in the inner fjord than in the outer part.

22. *Evadne nordmanni.* Scarce November—April, numerous May—October. In 1941 maxima in July—August and October, in 1942 in June. Numbers were always highest in the inner fjord.

23. *Podon spp.* a) *Podon polyphemoides.* In 1941 present May—October, numerous June—August. In 1942 scarce June—September. b) *P. intermedius.* Scarce July—October 1941, lacking in 1942. c) *P. leuckarti.* In moderate numbers June—October 1941 and April—September 1942. Maxima in May and June both years.

24. Larvæ of different decapods occurred in summer. Of great interest is the capture of larvæ of *Porcellana platycheles* Pennant from August 15. to October 10. 1941.

25. Euphausiids. Adults of *Thysanoessa inermis* were caught singly in the outer fjord from July 18. to September 12. 1941, larvæ were caught during all the time of investigation, in 1942 also in the inner fjord. Nauplii occurred June 6. 1941 and April 10.—21. 1942. One single calyptopis larva of *Meganyctiphanes norvegica* was taken in the outer fjord May 7. 1942.

26. *Sagitta elegans* in 1941 was confined to the outer fjord. In 1942 it was taken at all stations. Maximum of spawning occurred in August and October 1941, in May, June and possibly August 1942. Adults and eggs were mostly caught in the deeper water layers,

newly-hatched larvæ and younger individuals above 15 m. — Of *Sagitta setosa* a few specimens were caught.

27. *Oikopleura dicoica* was numerous June—December 1941, with maxima in July, August, and October. In 1942 it was scarce, most common in May.
28. *Fritillaria borealis* occurred abundantly. In 1941 with maxima in April, July, and October, in 1942 maxima (March), April, and May.
29. Larvae of different bottom evertebrates, mussels, polychætes, cirripedians and others, were fairly numerous, especially in the autumn.
30. 20 species of c o e l e n t e r a t a were idenfied with more or less certainty. In 1941 *Melicertum octocostatum* was the most common medusa, in 1942 *Sarsia tubulosa.*

    Of the ctenophora, *Pleurobrachia pileus* was fairly abundant, with mass occurrences of eggs and larvæ in June, August, and September 1941.

    Larvæ of *Cerianthus lloydi* were found in 1942.
31. Of the turbellaria, *Alaurina composita* and larvæ of *Notoplana almata,* or nearly allied species, were caught.
32. Fish eggs and larvæ, chiefly of *Clupea sprattus,* some also of *Pleuronectes flesus, P. limanda, Gadus callarias* and *G. merlangus,* were taken in May—August 1941 and April—July 1942.

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Table 7. The percentage distribution of each stage of Calanus finmarchicus in the Nordåsvatn 1941—42.

Date	Inner Fjord								Outer Fjord							
	♂	♀	V	IV	III	II	I	N	♂	♀	V	IV	III	II	I	N
18—25/7	1.4	1.4	6.1	6.6	13.6	9.9	30.5	30.5	6.0	20.7	18.9	14.3	5.5	12.5	—	21.1
1—15/8	1.4	6.9	11.7	11.2	12.7	9.4	10.1	36.6	8.9	17.4	16.8	15.6	12.6	3.8	1.4	23.5
22—29/8	1.4	4.4	7.5	5.0	8.9	10.2	15.2	47.4	2.1	11.7	16.1	18.2	18.7	9.1	9.1	15.0
5—12/9	1.1	1.1	3.4	6.7	5.6	11.2	9.0	61.9	6.3	25.4	21.0	5.6	3.7	2.1	1.4	34.6
18—26/9	0.4	0.8	7.1	8.7	9.9	8.3	10.3	54.5	2.4	10.8	7.0	2.6	3.6	2.6	2.6	68.4
3—10/10	2.0	3.3	9.2	13.2	12.3	11.4	7.7	40.8	0.3	2.5	7.0	11.5	13.6	14.2	15.3	35.6
24/10	2.6	4.9	9.8	9.6	9.1	15.7	15.2	33.1	6.8	13.6	29.4	13.0	9.6	—	7.9	19.6
1—12/12	—	1.7	52.8	16.5	12.4	6.6	4.1	5.0	—	4.5	24.9	10.7	4.5	1.5	15.4	38.5
10/4	—	0.4	0.1	0.4	1.0	7.7	19.1	71.3								
21—29/4	1.0	1.0	5.9	22.1	32.3	21.9	12.1	3.7	1.2	0.5	8.3	15.9	23.7	22.4	14.0	11.9
7—15/5	2.9	4.8	28.5	49.3	8.8	1.0	0.8	3.9	4.5	3.0	18.8	35.1	18.3	12.8	3.0	4.5
22/5	3.4	5.1	39.8	31.8	0.7	2.1	1.5	15.6	6.1	4.6	30.3	13.7	6.1	3.6	2.5	33.1
2—12/6	0.9	2.2	55.4	14.8	5.7	5.8	3.1	12.0	1.1	3.0	17.0	2.6	11.2	18.6	3.4	43.1
23/6	0.5	1.0	72.9	17.8	5.3	0.6	—	3.7	1.9	4.7	86.8	6.6	—	—	—	—
8—14/7	—	1.2	55.6	15.8	0.9	4.2	0.5	22.0	1.0	6.7	55.2	3.8	13.3	20.0	—	—
18/9	5.0	7.5	34.8	14.9	9.4	4.0	2.0	22.4	4.0	17.4	7.2	5.6	—	—	0.8	65.0

0,50 0,8

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ON THE TIDAL WATERS IN THE NORDÅSVATN

A home-made, self-recording Tide-gauge

By
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SAMBAANDETS TRYKKERI — BERGEN 1944

On the Tidal Waters in the Nordåsvatn.

A home-made, self- recording tide-gauge.

Stimulated by Mr. G. Rollefsen, The Directorate of Fisheries, Bergen, I made in the autumn of 1942 a rather primitive self-recording tide-gauge and mounted it at Kråkenes in the Nordåsvatn in order to have it tried. In spite of its simple construction it was found to give quite distinct records of the daily and weekly periods, besides showing some typical traits of the tide disturbances.

Fig. 1 shows the registrator. The floater *F* is an ordinary bottle, half filled with water and floating inside a tube. A narrow opening in the bottom of the tube reduces the disturbing effects of surface wawes on the record. By means of a piano string the movements of the bottle are transmitted to the larger wheel *H* on the gauge. A smal-

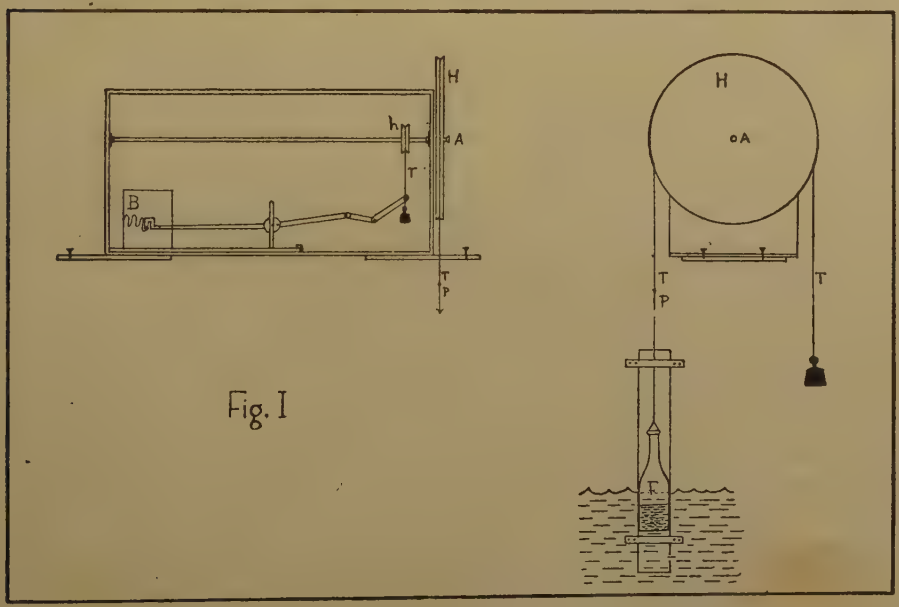

Fig. I

ler wheel *h*, mounted on the same axis, serves to reduce the scale to 1 : 10. In order to increase friction rope is used round both wheels instead of string. The motion of the wheel *h* is finally transferred to a lever arrangement, one arm of which is used for adjusting the scale by regulating its length. The other arm is provided with a pen that records on an old barograph-drum, making one revolution a week. Ordinary barograph paper is used, and the movements of the floater with the tide can be read with an accuracy of about $\pm$ 0,1 cm ($\pm$ 0,1 mm on the record.)

Fig. 2 represents the records obtained from October 12. to November 17. 1942. During that period the daily amplitude is about 10 cm and the greatest difference is 65 cm, from 78 cm (neap) to 143 cm (spring).

Fig. 3 illustrates the average height of water, the curve being obtained from the 2-hourly readings of the original records by forming consecutive means of 12 values.

Fig. 5 shows the delay of high and low water at Kråkenes compared with high and low water at Vatlestraumen (outer fjord). The average delay is about 2 hours and it seems to decrease with increasing average height of water. This is no doubt due to the narrow and shallow entrance to the Nordåsvatn at Straume, where the transport of water pr. unit of time is relatively very much increased with an increasing average height of water.

The weekly period of the tide is distinct, but several times disturbances can be seen to have occurred. The wind seems to be the cause of these irregularities as southerly and westerly winds have the effect of piling up the water in the Nordåsvatn, and easterly and northerly winds of brushing it out towards the sea. Trying to justify this point of view I have plotted in fig. 6, after Beaufort scale, the southerly and westerly winds upwards from a zeroline and the easterly and northerly winds downwards in the same way, and a comparison between fig. 6 and fig. 2 seems to confirm the theory. This elevation of the water must partly be seen as a local stowing of the water in the Nordåsvatn itself, and partly as due to a general stowing of the coastal water.

Fig. 7 shows the rainfall. When not occurring in greater quantities the precipitation does not seem to have any notable influence on the height of water. However a decrease of amplitude and the great elevation of water on November 14. and 15. seems to be caused by the rainfall. (The observations on wind and rainfall are from Fredriksberg, Bergen).

It must be borne in mind that this was no scientific research, but

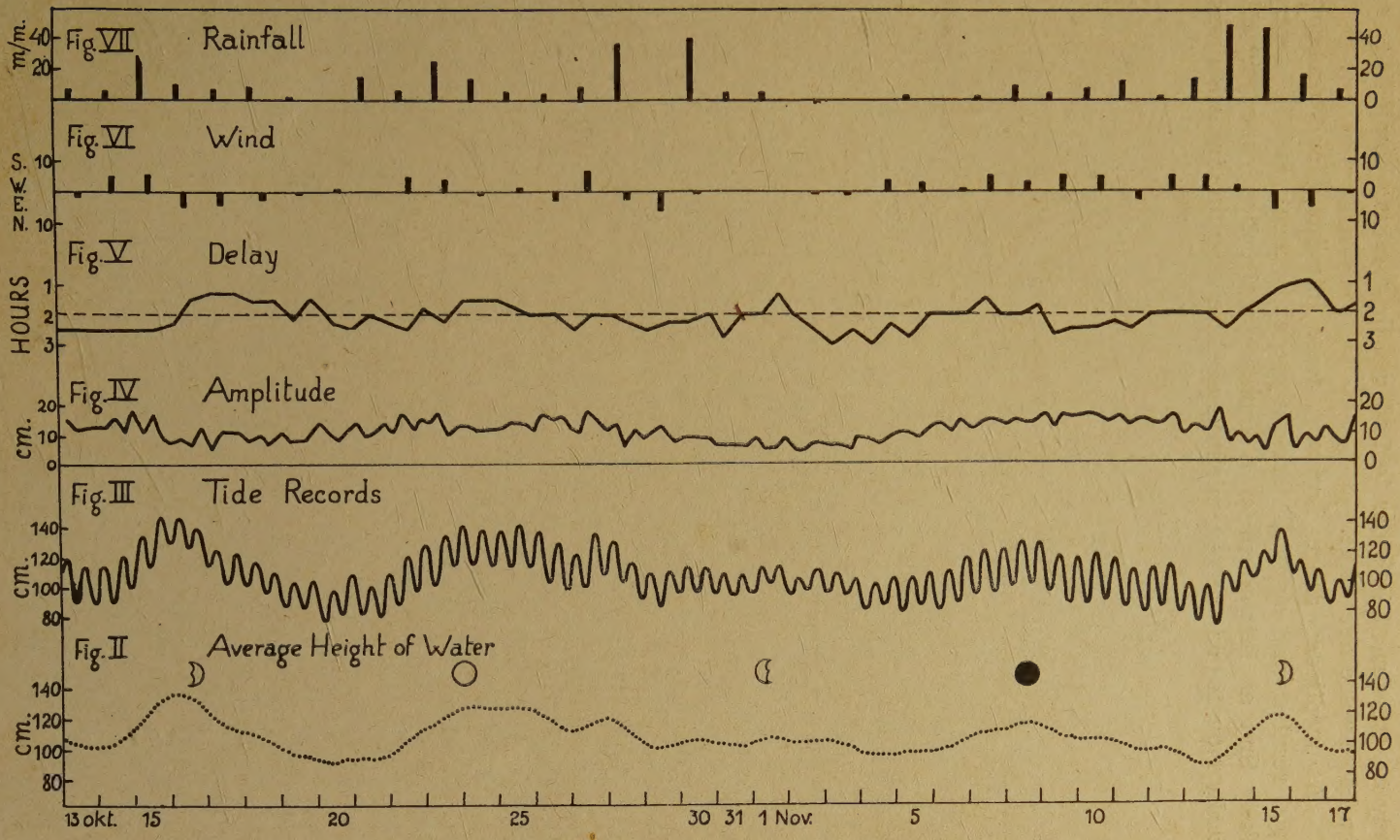
Fig. VII Rainfall
m/m.
40
20
0
Fig. VI Wind
S.
N.
10
E.
W.
Fig. V Delay
HOURS
1
2
3
Fig. IV Amplitude
cm.
20
10
0
Fig. III Tide Records
cm.
140
120
100
80
Fig. II Average Height of Water
13 okt.
15
20
25
30
31
1 Nov.
5
10
15
17

only an experiment in order to find out the working possibilities of the home-made tide-gauge.

As mentioned above, however, some interesting and probably good results were obtained through the experiment, and it is very likely that an instrument of a similar construction, when scientifically mounted and served, might be used for scientific investigations.